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STEREOMICROSCOPIC STUDY OF THE SURFACE OF THE LUNG

I. DESCRIPTION OF THE METHODS USED

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In 1928 capillaroscopic studies of the alveolar capillaries were made on the anesthetized dog through a thoracotomy opening.[1] In these experiments a Zeiss capillaroscope was used (fig. 1). It offered a satisfactory visualization of the alveolar capillaries through the transparent virgin visceral pleura. The details of the alveolus were not distinct, and it became obviously necessary to see the saccules in more than one dimension by means of stereoscopic visualization. An opportunity for such study has been offered by the Zeiss surface stereomicroscope with a complete double lens system. This microscope may be used with the ordinary small stand, particularly for the study of smaller blocks of tissue from the lungs (fig. 2). It may be used with a larger adjustable stand also, so that the whole lung may be studied in the living or the dry state (fig. 3).

The illumination is so adjusted that light is reflected from the upper surface of the object. Use of this principle is made both in the stereomicroscope and in the capillaroscope. The advantage of this type of lighting lies in the fact that objects of any size or thickness can be studied at the exposed surfaces. Microscopic examination of the surface is particularly adaptable to the study of the lung because of its sponginess and its many combinations of sacs and skeletal structures.

The microscope offers the added advantage that it can be held by the hand for microscopic study much as the telescope is held for the study of distant objects. It also has an interchangeable system of

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1. Olkon, D. M., and Joannides, M.: The Capillary Circulation of the Alveolus Pulmonalis in the Living Dog, Arch. Int. Med. **45**:201-205 (Feb.) 1930; Capillaroscopic Appearance of the Pulmonary Alveoli in the Living Dog, Anat. Rec. **45**:121-126 (March 25) 1930.

lenses and objectives, so that various magnifications may be obtained by changing either the oculars or the objectives. For small magnifications only for the study of the gross variations of the pulmonary ele-

Fig. 1.—The Zeiss skin microscope, as suggested by Professor Müller of Tuebingen.

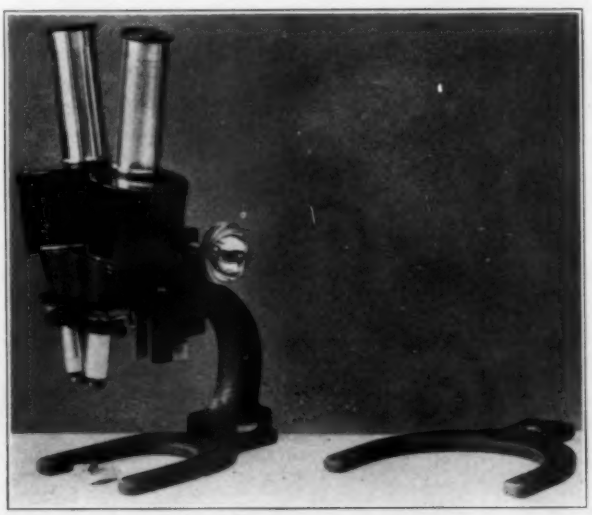

Fig. 2.—The Zeiss surface stereomicroscope.

ments, this method is satisfactory. For the larger magnifications, at which the focal point changes with even the slightest motion, the adjustable stand was found most efficient (fig. 3).

THE CAMERA

For purposes of reproduction a stereomicroscopic camera made by Zeiss (fig. 4*A*) was used. This camera has two dark chambers and makes two stereoscopic exposures at one sitting. The system of lenses used for the microscope can be used with the camera. For better reproduction of detail the Wratten emulsion was placed on glass plates. The plates, being of an odd size, had to be made specially. For larger magnifications of the pictures I attached a magnifier to the top of the camera (fig. 4*B*), but this procedure has not given clear pictures, especially in the greater micromagnifications.

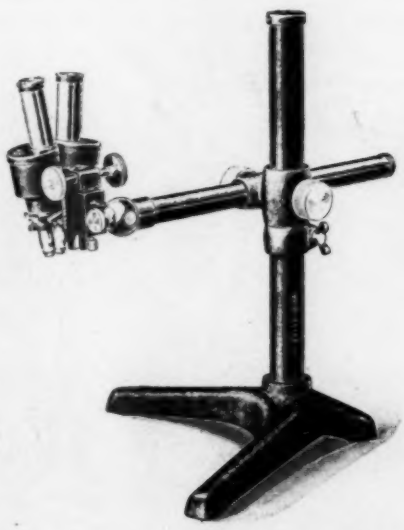

Fig. 3.—The larger adjustable stand for the study of large specimens of the lungs of anesthetized animals.

LIGHTING SYSTEM

Illumination was obtained by using a carbon arc lamp with the rays directed to the field of vision. In the living animal I wished to avoid changes due to drying by the heat of the light projected at the field. Accordingly, I either kept the part of the lung cool by soaking it with physiologic solution of sodium chloride or used a less powerful system of lighting. In this system a small electric bulb was used and the light projected to the spot by means of lenses.

STUDY OF THE LUNG IN VIVO

The specimens of lung were prepared in one of various ways, according to what I wished to study. For study of the lung in the living animal a thoracotomy with artificial respiration was sufficient. A por-

tion of the lung was taken out, and care was taken to avoid as much as possible an excessive exposure of the remaining intrathoracic organs. The exposed lung expanded and collapsed with intermittent intratracheal artificial respiration.

Because artificial respiration introduced variable factors, namely, the rate, the volume and the pressure of the blast of air, I tried to eliminate it from the study of the lung. After extensive search I noted that the lung of the alligator expands and collapses when the chest is open. This phenomenon is due to the fact that the lung is adherent to the dome of the chest and also to the diaphragm. On section of the lung in this animal, I noticed also a circular contractile tissue that aids in opening and closing the apertures to the alveolar elements of

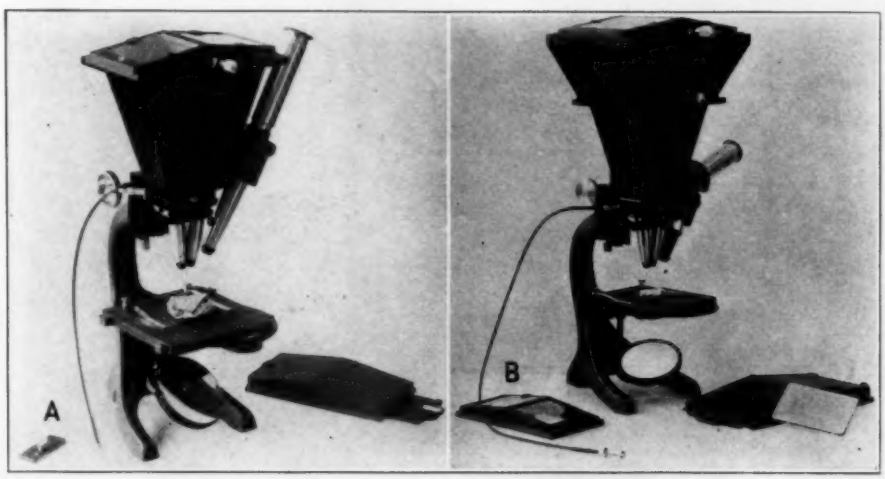

Fig. 4.—*A*, the Zeiss stereomicroscopic camera. This camera may be attached to the smaller or the larger stand. *B*, stereomicroscopic camera with a magnifier in situ.

the lung. The alligator can be easily put to sleep by means of a few drops of chloroform or ether placed on a cotton pad and pushed into its mouth.

For the study of the capillaries of the lung, the frog has given the best results. After pithing the animal, I inserted a small glass tube into the trachea and allowed just enough air to flow into the lung to produce fair distention. If too much pressure is exerted in the trachea the blood in the capillaries is squeezed into the larger vessels, and the capillaries are filled with air emboli. This occurrence causes no apparent injury to the vessels.

STUDY OF SPECIMENS OF LUNG

The ordinary pathologic or normal specimens of lung were studied after fixation with Kaiserling's solution or solution of formaldehyde. For special studies, after preliminary tying of the pulmonary vessels, I filled the bronchial tree with the fixing solution in addition to dipping and keeping the specimen in it.

In some specimens, after preliminary ligation of the vessels, I allowed air to run into the bronchial tree at a pressure just great enough to produce distention of the lung. Overdistention produced pleural bullae. Air was run into the lung until it was completely dry, and it was then divided into large blocks for study. In order to avoid overdistention the air was blown through a T tube, one end of which was attached to the lung and the other to a screw clamp. The outflow of air was regulated by tightening the screw clamp up to the point at which the optimum expansion of the lung was obtained.

For the study of the lung of a large animal, such as the cow, it was necessary to avoid decomposition of parts of it preliminary to drying. I found it more satisfactory first to fill the bronchial tree with solution of formaldehyde U. S. P. diluted 1 to 10 and then to distend the lung. Such a fixation of the bronchial and bronchiolar elements often aids in producing a sponge effect on the lung. One can then take a piece of dry lung and soak it in water, thus filling the alveoli with clear water and offering another means of study. If the lung is not treated in this manner and is only dried in the distended state, it crumples into a mass of gelatinous material when it becomes wet. The dry specimens must be handled with great care because they crumple easily. In cutting various blocks for study it is necessary to use a thin, flat, sharp knife.

ANIMAL SPONGES

Fixation of the bronchial tree with solution of formaldehyde for the production of animal sponges is practical and is a means of getting soft sponges. Because of the expense involved in their production, sponges of this type are, at least at present, not commercially practical.

PREPARATION OF PHOTOGRAPHS

The reproductions obviously must be developed in absolute darkness or under a dim blue light. Wratten films are sensitive even to red light. In order to keep the plates in their respective positions I made it a rule to draw a line with a wax pencil along the inner border of

each of the two plates. This line was drawn on the glass side, so that it could be wiped off when the positives were made. The positives were mounted on cardboard under stereoscopic vision so that proper distances and adjustments could be made. This step is most important and means the difference between successful accurate visualization and unsightly inaccurate views on the stereoscopic cards.

The Zeiss Company furnished the photographs of the microscope and of the camera.

STEREOMICROSCOPIC STUDY OF THE SURFACE OF THE LUNG

II. THE ANATOMIC AND PHYSIOLOGIC STRUCTURE OF THE NORMAL LUNG; RÉSUMÉ OF OBSERVATIONS BASED LARGELY ON STEREOMICROSCOPIC STUDY OF THE SURFACE OF LUNGS FIXED AND IN THE LIVING STATE

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This report is presented as a brief summary of the stereomicroscopic observations on the surface of the lung which I started in 1928. I have felt for some time that the ordinary sections by which the pulmonary structure is studied do not include sufficient tissue to show the structural architecture. Cellular details are easily seen from them, but the sponginess of the lung prevents determining except inferentially the grosser characteristics, interrelations and relation to the mother stem of the alveoli. By stereomicroscopic study of the surface it is possible to see an alveolus in its three dimensions and actually to study its structural, cellular and vascular detail. On first examination the worker will be amazed at the complexity of the variegated holes and strands appearing in every possible position. With sufficient patience he will discover to his pleasure and amazement a new treasure of information. It is hoped that those who undertake such a study will neither be overenthusiastic nor become greatly discouraged, because it will take months of persistent examination before the kaleidoscope of data will begin to assume its proper classification and form.

This work was started at the surgical research laboratories of the College of Medicine of the University of Illinois. I had an opportunity in 1929 to spend some time in Europe. When in Berlin, I was fortunate in being allowed by Prof. Max Busch to study the thoracic sections prepared by Prof. Koch,[1] on exhibit in the Museum of the Pathologische Abteilung of the Reichsarbeits Ministerium. These specimens, prepared during the World War, make an excellent collection of sectional views of the lung, showing its relation to the wall of the chest and to the adjacent intrathoracic structures. Practically all types of pulmonary lesions described in textbooks of pathology are found in this collection. I have made free use of most of the sections.

From the Department of Surgery, College of Medicine, University of Illinois.

1. Koch, W.: Thorakschnitte von Erkrankungen der Brustorganen, Berlin, Julius Springer, 1924.

On my return to the United States, the work has been continued to date at the University of Illinois. Little has been published so far on my observations [2] because the data obtained from this work appeared new and I hesitated to rush into print until I was certain of my ground. In another paper I discuss the technic in detail in the hope that some enterprising persons will carry on in this work and help supply the true picture of the structure of the lung under normal and pathologic conditions.

TRACHEA AND BRONCHI

The trachea occurs in all animals, including the amphibia. In the frog, the turtle and the alligator it ends abruptly as soon as it reaches the lung. In these animals one sees no bronchial ramifications but notices the structure of the alveoli, which will be described later. In the mammalia, the trachea and bronchi assume a characteristic architecture.

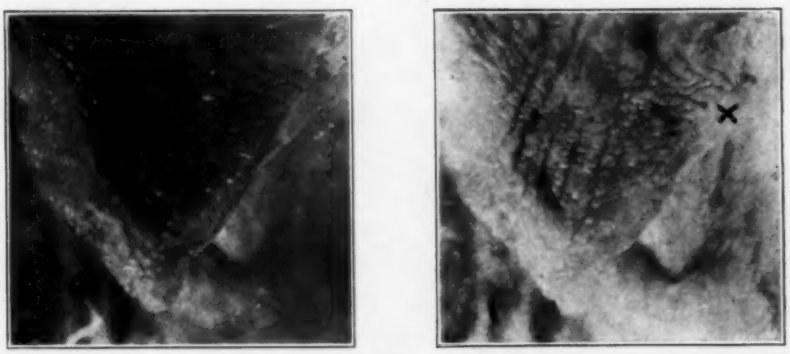

Fig. 1.—Stereomicroscopic view of the trachea. Note the longitudinal corrugations. At x the cross section of a cartilaginous ring is seen. Adjust the stereoscope to the proper focal point, and keep looking till you see depth; then study the detail.

The stereomicroscopic features of the trachea that have not been emphasized before are the trabeculations in its inner lining (fig. 1). One sees that in addition to the transverse trabeculations corresponding with the tracheal rings there are longitudinal trabeculations extending along its whole length.

The bronchi do not have any trabeculations and in my studies showed no special features not previously described. The branchings are given off at every possible angle, and the more peripheral the branches the greater is the number of the smaller branches. The angles at the branchings are generally acute (figs. 2 and 3).

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2. Joannides, M.: Structure of the Normal Lung: A Surface Stereomicroscopic Study, Arch. Int. Med. **47**:19-23 (Jan.) 1931. Joannides, M., and Steinman, F. H.: The Mechanism of Pneumonia, ibid. **47**:24-27 (Jan.) 1931.

The term terminal bronchioles was assigned to denote the subdivision of the lung known as the atrium in Miller's classification.[3] There is no atrium in the mammalian lung of the type that is seen in amphibia and reptiles. The terminal bronchioles have the same cellular characteristics as the alveoli. On looking into the lumen of a terminal bronchiole one sees a corkscrew-shaped tube within a tube, much like a circular staircase. In the casts made of Wood's metal or pyroxylin the terminal bronchioles appear bulbous and are made up of a series

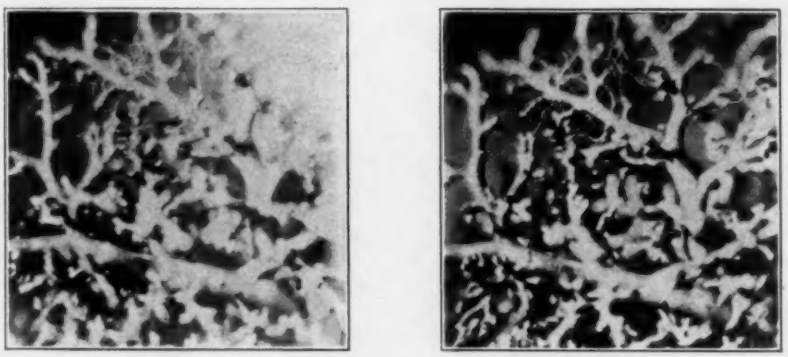

Fig. 2.—View of the smaller bronchi under low power.

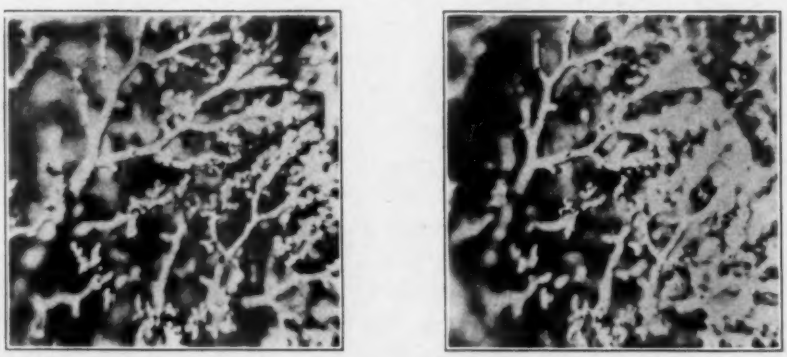

Fig. 3.—View of the smaller bronchi under low power. Note the bulbous effect at the terminal branchings of the bronchi.

of nodules arranged in more or less circular ridges. These ridges are separated by grooves, so that the general appearance of the structures suggests irregularly corrugated tubes. Each one of these circular corrugations appears to have a series of smaller cuplike grooves projecting into the wall of the terminal bronchiole. These grooves are approxi-

3. Miller, W. S.: Anatomy of the Lungs, in Reference Handbook of the Medical Sciences, ed. 4, New York, William Wood & Company, 1923, vol. 6, p. 82; The Lung, Springfield, Ill., Charles C. Thomas, Publisher, 1937.

mately the same size as those of the alveoli. The internal characteristics of the terminal bronchiole are those of a corkscrew-shaped tube with a bannister-like structure which represents the inner wall of the corrugated parts of the tube. Here one sees the bulbous projections into the outer wall of the "terminal bronchiole."

There is no evidence of any intercommunication between any groups of bronchi or bronchioles, except through the parent stem. My observations appear not to confirm the work of Van Allen and his associates,[4] who have described the presence of a collateral respiration.

STEREOMICROSCOPIC VIEWS OF THE SURFACE OF THE DRY LUNGS

The comparison of the lung to a tree is quite an apt one. The trunk of the tree is analogous to the trachea. There are generally no branches along the trunk. The larger bronchi may be compared to the larger branches of the tree. The bronchi of the third and fourth order may be compared to the smaller branches of the tree. These smaller branches give off more and more smaller branches till the final branchings are seen bearing the leaves. The alveoli of the lung serve much the same function as the leaves of the tree. Each leaf is so situated that it is fully exposed to the rays of the sun. So it is with the pulmonary alveoli. Each group of alveoli is so arranged as to take advantage of every available space in the thoracic cavity. Two neighboring groups of alveoli may have their origin from fairly distant secondary or even tertiary bronchi.

At the tips of the bronchial tree in the metallic or pyroxylin casts one sees clusters of small bulbs springing out of the end of the bronchiole. These appear much like warty projections and remind one of the terminal subdivisions of a cauliflower bulb. These cauliflower-like bulbs are attached to numerous terminal bronchioles much in the manner of a cluster of grapes (fig. 3).

The stereomicroscopic appearance of the dry, fixed, moderately expanded lung is much like that of the cut surface of a dry commercial sponge (fig. 4). At first glance, one sees a large number of various-sized holes which assume round, polygonal, triangular, or oval shapes. The blood vessels and bronchi appear as larger oval or round openings and the terminal bronchioles and alveoli as the smaller openings. The bronchus and two vessels are usually found in close proximity to one another.

THE ALVEOLI

The alveoli on the cut surface appear as saccules of various shapes, namely, polygonal, oval, round or triangular. In the dry specimen two

4. Van Allen, C. M.: Collateral Respiration, J. Orient. Med. **15**:35-45 (Sept.) 1931; Surg., Gynec. & Obst. **53**:16-21 (July) 1931; Ztschr. f. Anat. u. Entwcklngsgesch. **98**:453-465 and 466-474, 1932.

to three honeycomb compartments are seen within the saccule of the alveolus, produced by projections arising from its wall. The terminal portions of these septums are rounded into cuplike openings. Each opening is smaller than the area of the cup itself. The edge of the septum appears thicker and is the site of a larger capillary. The stoma of the alveolus has also a cuplike opening much like those of its compartments. The mouth of the opening is somewhat thicker than the rest of the wall, and the opening itself is narrower than the rest of the saccule. Here again one sees a larger capillary. This capillary extends into the interalveolar wall and thence to the larger vessels.

When magnified 48 times, the wall of the alveolus in the dry specimen begins to appear transparent, with distinct speckles. At first glance,

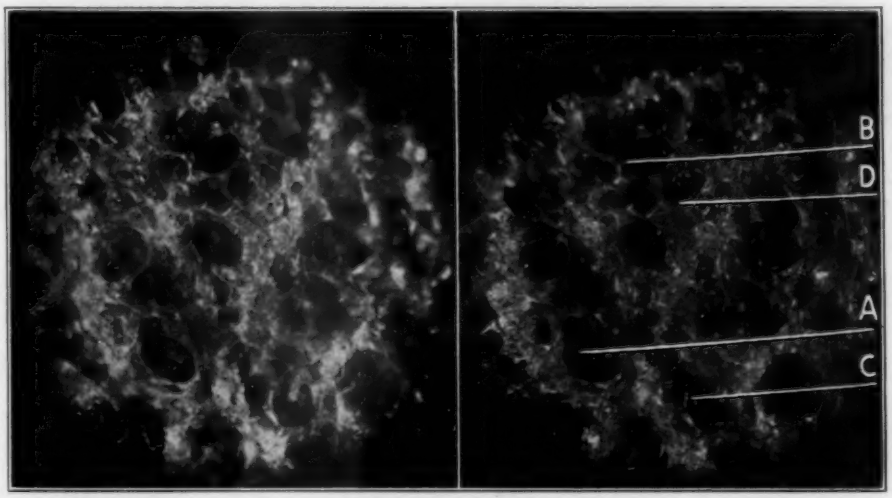

Fig. 4.—The characteristics of the alveoli. Note at the depth shown at *A* the cuplike recesses in the alveolus produced by the septums, the smaller diameter at the openings and the thin transparent wall of the alveolus. At *A* and *B* note the cross section of a terminal bronchiole and its relation to the alveoli. At *A* and *C* note the denser capillary of the cut alveolus whose terminal bronchiole originates from below. At *A* and *D* note some of the finer details of the thin alveolar wall.

one gets the impression that the alveolar wall is made up of a series of grooves and ridges, irregular in shape. On more careful examination, the ridges are seen to be the sites of the smallest possible capillaries, whose lumens allow only one red cell to pass through at a time. These capillary beds, being denser than the alveolar wall adjacent to them, are more refractive, and therefore one gets the impression of speckles between the ridges. The alveolar wall between the capillaries appears more translucent and sievelike. It is probably for this reason that pores have been previously described. I have not seen any such pores in

any specimens of normal lungs even when the lungs were overdistended to a capacity larger than that of the thoracic cavity (maximum visceral pleural capacity).

ALVEOLAR CAPILLARY CIRCULATION

The capillary circulation of the pulmonary alveolus was studied in the anesthetized alligator and in the pithed frog. The frog's lung when exposed had to be kept distended and allowed to collapse intermittently in order to get accurate readings. Care was taken not to overdistend the lung and squeeze air from the pulmonary saccule into the capillaries. Such overdistention can be easily accomplished even in the mammalia without causing any apparent injury to the alveolar wall itself.[5] The alligator's lung has a capacity of contracting and expanding without artificial inflation and offers a better means for the study of the capillary circulation of the alveolus. In order not to cause a tear in the lung the visceral pleural surface is studied for this purpose. It must be emphasized, however, that the alveolar wall is to be focused into the visual field and not the transparent pleural wall.

The one cell capillaries arise from the multiple cell capillary located in the periphery of the alveolar wall. These capillaries follow a rather tortuous course and terminate at the opposite multiple cell capillary. There is no apparent collateral ramification of the one cell capillaries. The alveolar wall is literally studded with them. The blood is seen to flow in one direction from one larger capillary, through the one cell capillaries, to that on the opposite side. I have not noticed any reverse flow of blood cells. At first glance, the course of the blood cells appears much like the wavy motion which is seen on the surface of a wheat field when a gentle wind blows over the plants. When the lung is fully distended or contracted, the flow becomes retarded. It is accelerated coincident with the process of distention or contraction. Similarly, with digitalization of the cardiac muscle, the flow of blood becomes retarded so that one can see the actual course a red blood cell follows in these capillaries. The blood cells are seen taking a rather tortuous, zig-zag course, always in the same one cell capillary, and finally reaching the larger capillary on the opposite side. The one cell capillaries appear more straight when the lung is distended and more tortuous when it is contracted (fig. 5).

I have not as yet made any study of the lymph and nerve supply of the lung. I am trying to find appropriate methods or differentiating

5. Joannides, M., and Tsoulos, G.: The Etiology of Interstitial and Mediastinal Emphysema: Experimental Production of Air Embolism, Acute Spontaneous Pneumothorax, Acute Pneumoperitoneum, Interstitial Mediastinal and Retroperitoneal Emphysema, Arch. Surg. **21**:333-339 (Aug.) 1930.

vital stains so that I can trace these two important attributes of the lung in the living animal.

PLEURAL SURFACE OF THE LUNG

The pleural surface of the lung yields no new observations. The checkered appearance of the human lung, especially in the presence of anthracosis, is well known to all. This appearance is most noticeable in the lungs of cattle and least noticeable in those of sheep. The lobulations of the pleural surfaces are of definite importance teleologically. The pleural projections into the lobules of the lung prevent the rupture or injury of large portions of the lung [6] (fig. 6).

One fact of importance must be emphasized because of its clinical applications. At various areas one sees a bulla corresponding to the lumen of the underlying bronchiole. Careful study of such areas reveals

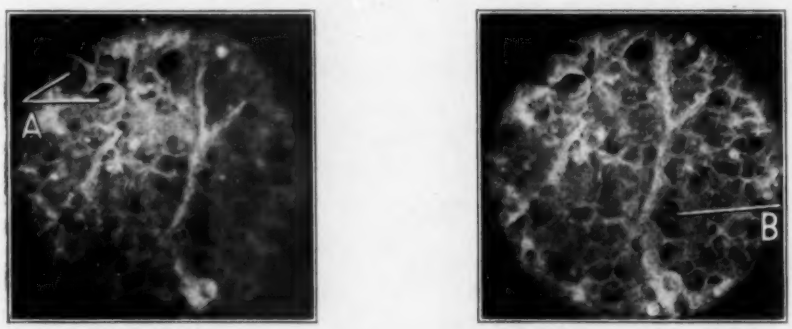

Fig. 5.—Distribution of pulmonary vessels. The vessels are injected and emphasize detail in the smaller branches. At *A* the characteristics of the inner surface of the bronchus are shown. At *B* the characteristics of a terminal bronchiole are shown.

that here and there a bronchiole ends abruptly underneath the pleura without any alveolar subdivisions. It is frequently in areas such as these that injury to the lung occurs when there is a sudden increase of intrabronchial air pressure. The pleura ordinarily acts as a water-tight and air-tight sheath of the lung. It can be peeled off easily if one exerts in the lung of a dog or in an excised human lung a sudden pressure of 100 mm. of mercury in repeated blasts of air. The pleura loses its adhesive power, and a bulla forms which enlarges as far as the boundaries of the pulmonary lobules. If the pressure is maintained long enough (thirty to sixty seconds) the pleural bulla may rupture and cause a spontaneous pneumothorax.[5]

6. Joannides, M.: Protective Power of the Pleura, Am. J. M. Sc. **180**:833-836 (Dec.) 1930.

REPAIR OF PULMONARY INJURIES

The lung contains a thick yellow gelatinous substance which acts as an adhesive agent in case of minor injuries. Injury to the lung without injury to any larger bronchi or vessels causes this substance to fill in the space and promptly stop the air from leaking out of the injured part. In a few minutes it appears as a thick cover so that bubbles of air can be seen underneath it. In the dog one can easily demonstrate the presence of this substance by making a stab wound in the lung. The air now begins to leak through, and along with it is noticed this substance, mixed with blood. To hasten the cohesion one may take the two cut portions, approximate them and exert a slight pressure with the thumb and index finger. Within thirty to sixty seconds the lung appears again completely air tight and water tight, as if no injury had occurred.

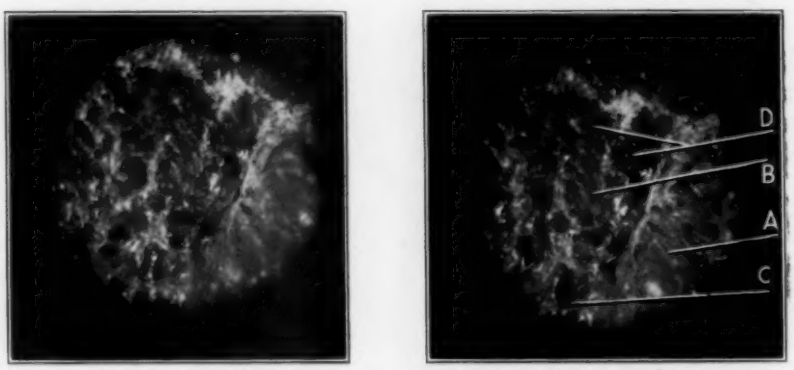

Fig. 6.—The characteristics of an interlobular septum. At *A* note the particles of coal embedded in the wall of the alveolus. At *B* note the characteristics of the alveolus. At *C* note the comparative greater thickening at the mouth of the sacule. At *D* note the relatively loose relationship of the alveolar elements to the interlobular septum.

EXTERNAL RESPIRATION IN THE ALLIGATOR'S LUNG

The presence of a circular contractile ring in the atrium of the alligator's lung has been noticed. This ring functions in connection with external respiration. It reaches its maximum closure at the end of inspiration and then gradually dilates and reaches its maximum dilatation at the height of expiration and the beginning of the inspiratory phase.

EFFECT OF CARDIAC CONTRACTIONS ON THE VOLUME OF THE LUNG

Observation of the lung through a thoracoscope and also through a fluorescent roentgen screen reveals an interesting phenomenon. The

whole lung expands slightly at a moment coincident with the cardiac systole. This increase in pulmonary volume disappears during the diastolic phase of the cardiac cycle. One gets the impression of a pulsating lung coincident with the cardiac contractions. Under the fluoroscope the pulsation becomes obvious when the lung is partially collapsed with artificial pneumothorax and the intrapleural pressure is negative. It may be possible by studying the amount of intrapleural pressure necessary to eliminate this pulsation as seen in the fluoroscopic screen or on a recording drum to find a clinical method for studying the changes of pressure in the pulmonary circulation.

SUMMARY

1. A study of the normal structure of the lung, both in the fixed and in the dried human specimens and in the living animal, such as the frog, the turtle, the alligator and the dog, shows that the lung presents the same fundamental architecture in all these animals. Variations consist primarily of the greater complexity in the mammalia. The frog's lung may be looked on as a magnification of the general structure of an alveolus. The relation of the atrium to the terminal bronchiole can be noticed definitely in the lung of the turtle.

2. Casts of the bronchial trees of mammals show that the greatest number of ramifications are given off by the smaller branches of the bronchial tree. These findings suggest an analogy to the branching of large shade trees.

3. The terminal bronchiole, or atrium of Miller's classification, is seen as a corkscrew-like cochlea-shaped tube with a circular cup-shaped groove enclosed within the various corrugations of the wall. There is a gradual transition in the bronchial tree from the tracheal type of structure in the larger bronchi to the alveolar type in the terminal bronchioles (figs. 7 and 8).

4. The pleural surface of the lung offers an opportunity for the study of the pulmonary alveolus. The pleura is transparent and easily placed out of focus.

5. The normal alveolus is a small round, oval, triangular or polygonal sac with two or more compartments produced by septums arising from the alveolar wall. The alveolar stoma is smaller than the sac, both in the alveolus and in its compartments.

6. The alveolar capillaries flow in one direction without any back flow. There is no apparent collateral capillary circulation. The capillaries follow a tortuous course along the surface of the alveolar wall and reach the larger capillary on the opposite end of the wall.

7. The visceral pleura acts as a loosely adherent air-tight and water-tight covering of the lung, and its boundaries are those of the lobules.

8. The lung contains an adhesive substance that heals its minor injuries.

9. Some bronchioles may be seen to terminate abruptly underneath the visceral pleura. I believe that this condition is frequently the cause of spontaneous pneumothorax.

10. A diligent search for collateral respiration and the presence of alveolar pores [7] has failed so far to show me the existence of either one or the other.

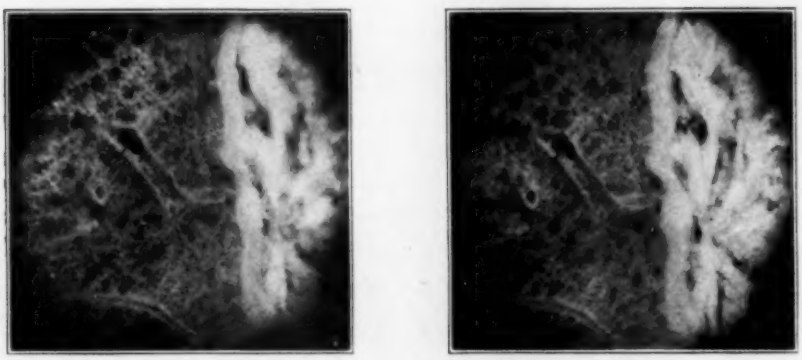

Fig. 7.—Longitudinal section of a bronchiole. Note the gradual change from bronchial to alveolar architecture.

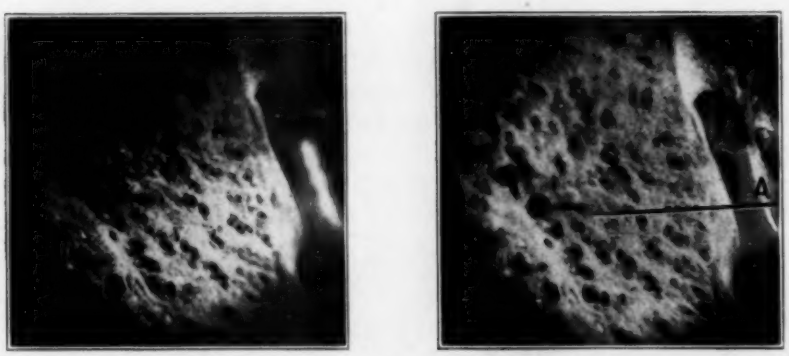

Fig. 8.—Section made in a case of carcinoma of the lung. Pulmonary implantations of cancer originating in the mediastinum. Note the disappearance of the alveolar elements and the transfer of the respiratory function to the terminal bronchioles.

11. W. S. Miller came closest to describing the actual structure of the alveolus through his reconstructional studies.

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7. Macklin, C. C.: Alveolar Pores and Their Significance in the Human Lung. Arch. Path. **21**:202-216 (Feb.) 1936.

CHRONIC APPENDICITIS

IS IT A CLINICAL ENTITY?

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This study was undertaken in an attempt to determine whether or not there is such a clinical entity as chronic appendicitis. The subject has been approached from the following three angles: First, the pathologic changes in appendixes supposed either before or after the operation to have been the cause of symptoms have been compared with the changes in those which apparently had never been the cause of symptoms. Second, the incidences of pathologic changes in appendixes supposed to have been the cause of symptoms have been determined according to symptoms, physical findings, laboratory findings, sex and age. Third, the percentages of the patients followed up who remained free from symptoms have been determined according to the pathologic change found in the appendix and the other classifications just listed.

In a study [1] made of the appendix in cases in which nothing in the history or physical findings indicated any present or past disease of that structure, in two thirds of the cases there was found to be definite pathologic change (table 1). The incidences of inflammatory changes in the appendix for the total number of cases in which it was not the cause of symptoms, both when some other inflammatory lesion existed in the abdomen and when no other inflammatory lesion was noted, are also listed. The latter incidence was chosen for purposes of comparison in this study, as it was considered to be the nearest approach to the expectation of pathologic change in the appendix when the patient has been erroneously operated on for chronic appendicitis. Reference will be made to these figures as a standard for comparison throughout the paper.

The time covered was the same in the two series of cases, the eleven year period from 1925 to 1935. The cases studied included those of all patients operated on within this time in the wards at St. Luke's Hospital whose symptoms were attributed, either before or after the operation, to

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From the Surgical Services of St. Luke's Hospital.

Presented before the Hospital Graduates Club, March, 25, 1937.

1. Shelley, H. J.: The Incidence of Asymptomatic Pathologic Conditions in the Appendix, Based on Study of 2,065 Consecutive Incidental Appendectomies, Arch. Surg. **35**:621 (Oct.) 1937.

a nonspecific chronic inflammatory lesion in the appendix. Eight hundred and eighty-one appendectomies met these requirements. For clarity, the various percentages throughout the paper have been stated as the nearest whole number, unless the percentages were so small that accurate comparisons could be made only by retaining the fraction. When comparisons were made of the incidences of pathologic change in various groups, these incidences were calculated on the total number of appendixes in each group. The incidences in relation to the total number of cases studied are given in the tables as well as the percentages of follow-up cures.

TABLE 1.—*Incidence of Inflammatory Change in the Appendix Without Symptoms or Physical Findings*

	Total Cases	Total Without Inflammation*	Normal*	Atrophic*	Total with Inflammation*	Simple Chronic Appendicitis*	Total with Marked Changes*	Chronic Catarrhal Appendicitis*	Chronic Exudative Appendicitis*	Acute Appendicitis*	Chronic Obliterative Appendicitis with Infiltration*	Chronic Obliterative Appendicitis without Infiltration	Chronic Periappendicitis*	Acute Periappendicitis*
Appendixes studied.....	1,890	37	33	3.9	63	30	33	4.3	8.3	1.8	5.6	9.7	1.6	1.2
Inflammation elsewhere in the abdomen.....	751	32	29	3.1	68	34	35	3.6	8.4	1.3	6.3	8.5	3.6	3.1
No inflammation elsewhere in the abdomen†..	1,139	41	37	4.3	59	28	31	4.8	8.3	2.0	5.2	10.5	0.4	0.0

* All the statistics are stated as the incidence per cent of the total number in each group.
† The incidence when no inflammation was present in the abdomen other than in the appendix (lower line of figures) is considered as representing most closely the findings to be expected when the condition in the appendix is not the cause of the patient's symptoms.

The percentages of follow-up cures were established as follows: A total of 704, or 80 per cent, of all the patients were followed for an average of twelve and a half months. Of these patients, 87 per cent had no return of the symptoms which were the indications for their operations. The percentages of cures stated in the tables were calculated by dividing the number of persons having no return of their preoperative symptoms by the total number followed in each group. For the larger groups, the resulting figures may be considered satisfactory for purposes of comparison. When but a few cases fall within a group, the percentage of follow-up cures can be taken as only an indication of the success of the operation.

MICROSCOPIC PATHOLOGIC OBSERVATIONS

Listed in table 2 are the appendixes according to microscopic pathologic changes; for each group the incidence, the comparable incidence when no symptoms were noted and the percentage of follow-up cures

are given. The pathologic processes other than nonspecific inflammatory changes or their absence will be discussed later. A comparison of the incidences of microscopic pathologic change in the presence and in the absence of symptoms is presented graphically in chart 1 *A*. Only 28 per cent of the patients showed no inflammatory change, as compared with 41 per cent in the absence of symptoms. This difference was due entirely to the decrease in the incidence of normal appendixes from 37 to 24 per cent. All appendixes which were normal, relatively normal or without definite pathologic change were listed as normal. The incidence of atrophic appendixes did not vary, being 4 per cent whether

TABLE 2.—*Incidence and Follow-Up Cures According to Microscopic Pathologic Observations* *

	Appendixes	Incidence, per Cent	Standard Incidence†	Per Cent Cured
No microscopic examination	6	0.7	...	100
Mucocele	2	0.2	0.2	100
Diverticulum	2	0.2	0.1	100
Lymphoid hyperplasia	1	0.1	0.0	...‡
Tuberculosis	2	0.2	0.3	100
Tumors	7	0.8	0.3	100
Total without inflammatory change	247	28	41	80
Normal	213	24	37	81
Atrophic	34	4	4	74
Total with inflammatory change	623	72	59	89
Simple chronic appendicitis	218	24	28	90
Total with marked changes	405	47	31	89
Chronic catarrhal appendicitis	54	6	5	91
Chronic exudative appendicitis	235	27	8	87
Chronic obliterative appendicitis with infiltration	84	10	5	92
Chronic obliterative appendicitis without infiltration	32	4	11	85
Total	881§	100		87

* These figures are more readily studied in chart 1.
† The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.
‡ No follow-up was made in this case.
§ Nine appendixes fall within two classifications each.

symptoms were present or not. This is somewhat surprising, as this condition is probably due largely to pressure, which might well be expected to cause symptoms in the right lower abdominal quadrant.

As contrasted to the foregoing observations, 72 per cent showed some type of inflammatory change—an increase from 59 per cent in the absence of symptoms. Simple chronic appendicitis was found in only 24 per cent of the cases, as compared with 28 per cent when symptoms were not noted. Therefore, the entire increase in incidence of inflammatory changes was due to the increase in the incidence of marked changes, 47 per cent as compared to 31 per cent. This increase was not uniform in the various types of change considered under the classification of marked changes. The incidence of chronic catarrhal appendicitis presented practically no variation, 6 per cent as compared to 5 per cent. The incidence of chronic exudative appendicitis was more

than tripled, from 8 to 27 per cent, while that of chronic obliterative appendicitis with infiltration was doubled, from 5 to 10 per cent. That the increased incidence of the two most active and extensive types of inflammation should account for the total increase in the incidence of inflammatory changes in the appendix is a particularly interesting point. The incidence of chronic obliterative appendicitis without infiltration was lowered, 4 per cent as compared with 11 per cent. This is a completely healed process without inflammation remaining.

The percentage of follow-up cures according to the types of pathologic change observed microscopically in the appendix are presented graphically in chart 1 *B*. The natural expectation is that the lowest

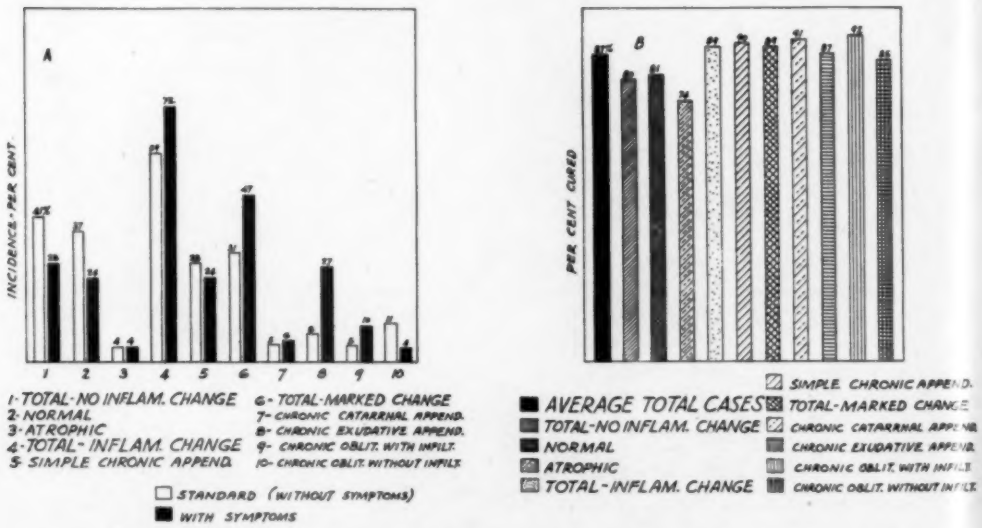

Chart 1.—*A*, comparison of the incidence of inflammatory changes in the appendix in the presence and in the absence of symptoms. The increase of the incidence of appendixes showing inflammatory changes in the presence of symptons attributed to the appendix is definitely shown. In cases of chronic obliterative appendicitis without infiltration, which is a completely healed process, a marked decrease in the percentage showing symptoms is found. *B*, percentages of follow-up cures according to the pathologic condition observed in the appendix. A greater percentage of follow-up cures is found in cases in which inflammatory changes were present. Of this group, the lowest percentage of cures is found in cases of chronic obliterative appendicitis without infiltration. That is as expected, but one would anticipate that the highest percentage would be found in cases of chronic exudative appendicitis.

percentage of follow-up cures would be found in the cases in which the appendix was without inflammatory change. This is borne out by the figures, 80 per cent for these cases as compared with 89 per

cent for those in which inflammatory change was presented. The proportion of follow-up cures in the cases in which the appendix was normal was 81 per cent. The reason that the difference was not greater will become apparent when these figures are broken down according to gross pathologic change. Again it is surprising that the cases involving atrophic appendixes not only showed no increase in the percentage of follow-up cures, as compared with those in which the appendix was normal, but that the lowest proportion of cures, 74 per cent, was found in this group.

In cases involving the various types of inflammatory change, there was a fairly uniformly high percentage of follow-up cures, regardless of the degree of deviation from the standard incidences or the severity of the inflammatory change. In cases of chronic exudative appendicitis, the lesion which presented the greatest increase in incidence over the standard and represents the most marked type of inflammatory change, the proportion of cures was only the average, 87 per cent. In cases of chronic obliterative appendicitis without infiltration, though the incidence of the condition is much less than the standard, the proportion of cures was the lowest; but this figure, 85 per cent, was only 2 points less than the average. The proportions of cures in cases of simple chronic appendicitis (90 per cent), chronic catarrhal appendicitis (91 per cent) and chronic obliterative appendicitis with infiltration (92 per cent) were all improved over the general average, of 87 per cent.

GROSS PATHOLOGIC CHANGES

In the study of gross pathologic change only adhesions and fecaliths were considered. Variations in the incidences of microscopic pathologic change according to gross pathologic change were found in several respects (table 3). Normal appendixes occurred more frequently in the presence of adhesions than in the presence of fecaliths, the incidence being 26 per cent as compared with 20 per cent. The incidence of atrophic appendixes in the presence of fecaliths, 6.5 per cent, was more than double that in the presence of adhesions, 3 per cent, and nearly double that when neither was present, 3.6 per cent.

The total incidence of inflammatory changes was practically the same whether adhesions, fecaliths or neither was present. However, the incidence of simple chronic appendicitis was increased to 26 per cent in the presence of adhesions and 30 per cent in the presence of fecaliths, as compared with 22 per cent when neither was present. A slight decrease in the total incidence of marked changes was found in the presence of both adhesions and fecaliths, 45 and 44 per cent, respectively, as compared with 49 per cent when neither was present. The incidence of chronic catarrhal appendicitis presented no changes. That of chronic

exudative appendicitis was less in the presence of adhesions, 22 per cent, than when neither was present, 29 per cent, while in the presence of fecaliths there was an increase to 32 per cent. Changes occurred in the opposite direction and were even more marked in the incidence of chronic obliterative appendicitis, both with and without infiltration: The incidence of the former was 13 per cent with adhesions, 9 per cent with neither and 4.5 per cent with fecaliths; that of the latter, 5.2 per cent with adhesions, 3.6 per cent with neither and 0.6 per cent with fecaliths. The incidences of microscopic pathologic changes when neither adhesions nor fecaliths were present conformed closely to the averages for the total number of cases studied.

TABLE 3.—*Incidence of Inflammatory Change in the Appendix According to Gross Pathologic Observations* *

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard†	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Adhesions	329	29	26	3.0	71	26	45	5.9	22	13.0	5.2
Fecaliths‡	154	27	20	6.5	73	30	44	5.8	32	4.5	0.6
Neither	387	29	25	3.6	71	22	49	6.7	29	9.0	3.6
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* Atrophic appendixes show a marked increase in incidence in the presence of fecaliths, as does chronic exudative appendicitis. Chronic obliterative appendicitis with and without infiltration and chronic exudative appendicitis present a marked increase in incidence in the presence of adhesions.

† The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

‡ Under this heading are included all appendixes containing fecaliths alone and those with fecaliths and adhesions together.

To summarize: Adhesions occurred more often in the presence of chronic obliterative appendicitis and with more than the proportionate number of normal appendixes; fecaliths, on the other hand, were associated particularly with atrophic appendixes and with chronic exudative and simple chronic appendicitis.

Adhesions about the appendix were found at 38 per cent of the appendectomies, fecaliths alone or with adhesions at 18 per cent and neither at 44 per cent (table 4, chart 2). The percentages of follow-up cures were good when adhesions were present and did not vary appreciably with the extent of inflammatory change, the figure being only slightly lower when no inflammation was present. When fecaliths were present, the findings were similar. However, when neither was found,

the cures remained good in the presence of inflammatory change but dropped to the lowest figure, 74 per cent, when this condition also was absent.

HISTORY AND SYMPTOMS

Nearly all of the patients were operated on because of one or more attacks of pain in the right lower abdominal quadrant. A few had had symptoms elsewhere in the abdomen, but after an exploratory oper-

TABLE 4.—*Incidence and Follow-Up Cures According to Gross Pathologic Condition*

	Total Cases	Incidence, per Cent	Per Cent Cured: Inflammation in Appendix: None	Slight	Marked	Total	Entire Group
Adhesions	331	38	87	91	88	90	89
Fecaliths*	156	18	85	94	90	91	89
Neither	394	44	74†	88	90	89	85
Total	881	100	80	90	89	90	87

* Under this heading are included all appendixes with fecaliths alone and those with fecaliths and adhesions together.

† The low figure for follow-up cures when no adhesions, fecaliths or inflammatory changes were present is outstanding.

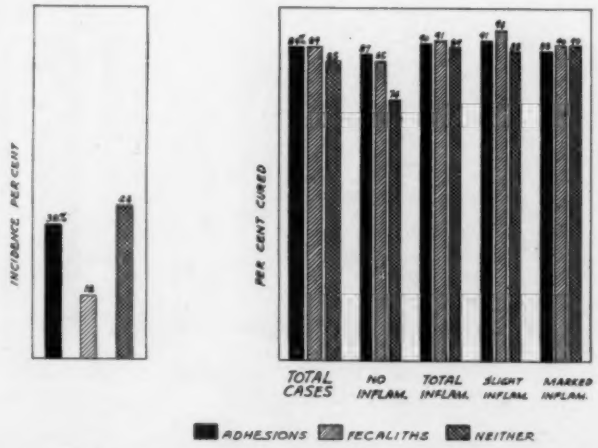

Chart 2.—Incidence and percentages of cures according to the gross pathologic condition. The increased percentage of follow-up cures in the presence of either adhesions or fecaliths is shown. In the absence of inflammatory changes, the presence of either of these two conditions brings the percentages of follow-up cures practically to that of the average of all the cases studied.

ation the symptoms were attributed to the appendix. Only 24 per cent were operated on in or following the first attack, while 45 per cent gave a history of multiple attacks over a period of one year or less and 31 per cent over more than a year (table 5, chart 3). The per-

centages of follow-up cures were remarkably high when the attacks were multiple and not extended over a longer period than one year. This was uniformly true regardless of the presence, absence or degree of inflammatory change. The lowest proportion of cures, 78 per cent, occurred when the operation was done during or following the first attack, and only moderate improvement resulted—cures in 82 per cent of the cases—when the history revealed multiple attacks over periods greater than one year. In both of the last two groups fewer cures

TABLE 5.—*Incidence and Follow-Up Cures According to the Time Covered by the Attacks*

	Total Cases	Incidence, per Cent	Per Cent Cured: Inflammation in Appendix: None	Slight	Marked	Total	Entire Group
First attack	213	24	65	89	79	82	78
Multiple attacks							
One year or less	392	45	95	96	97	97	96
Over one year	276	31	69	83	87	86	82
Total	881	100	80	90	89	90	87

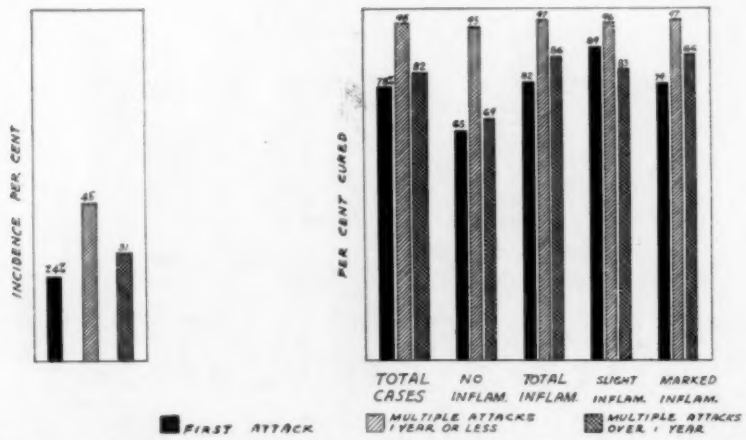

Chart 3.—Incidence and percentages of cures according to the time covered by the attacks. A uniformly high percentage of follow-up cures is found when the history indicates multiple attacks within a year, notwithstanding the presence, absence or degree of inflammatory changes. When the history indicates only one attack, the percentages of follow-up cures are the lowest throughout but vary according to the presence or absence of inflammatory changes.

resulted when no inflammatory change was found, 65 and 69 per cent, respectively. Curiously, however, the variation from the incidences of microscopic pathologic change in the absence of symptoms (table 6, chart 4) is exactly opposite to the percentage of cures. This is slight

although uniform. Chart 4 has been arranged to show this comparison by placing the groups in descending order according to the percentage of cures, i. e., those never having had symptoms, those having had multiple attacks for one year or less, those having had multiple attacks

TABLE 6.—*Incidence of Inflammatory Change in the Appendix According to Time Covered by the Attacks*

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard*	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
First attack	209	25	21	3.9	75	26	49	7.2	27	10.0	5.3
Multiple attacks—one year or less	390	30	26	4.8	70	26	44	5.4	26	9.6	3.1
Multiple attacks—over one year	271	28	25	2.6	72	23	49	6.6	29	9.6	3.3
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

Chart 4.—Incidence of inflammatory changes according to the time covered by the attacks. With one exception the group of cases in which a history of multiple attacks within a year was given shows an incidence of pathologic change nearest to that found when no symptoms had been attributed to the appendix. Only in the group comprising cases of chronic obliterative appendicitis without infiltration does the expected variation occur.

for more than one year and those submitted to operation during the first attack. Nausea and vomiting were mentioned in 66 per cent of the histories studied and reported as absent or not mentioned in 34 per cent

(table 7, chart 5 *A*). No definite relation was evident between its presence and the incidences of inflammatory changes (table 8), although the percentage of follow-up cures was slightly increased in its absence (table 7, chart 5 *A*). Constipation was mentioned in 42 per cent of the histories and reported as absent or not mentioned in 58 per cent (table 9, chart 5 *B*). In the cases in which the history was negative in this respect, a slight but definite increase of the incidences of inflammatory changes was found (table 10, chart 6). An even greater increase

TABLE 7.—*Incidence and Follow-Up Cures According to a History of Nausea and Vomiting*

	Total Cases	Incidence, per Cent	Per Cent Cured
Nausea and vomiting	580	66	86
None*	301	34	89
Total	881	100	87

* This classification includes all histories in which nausea and vomiting were said not to have occurred or were not mentioned.

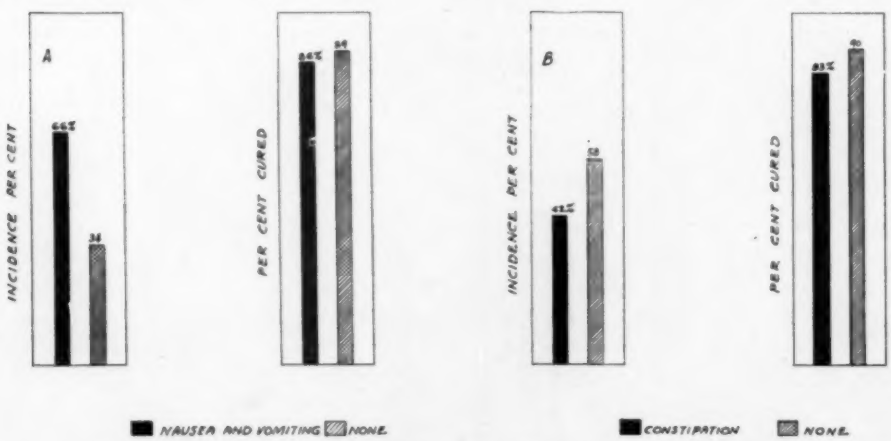

Chart 5.—Incidence and percentages of cures according to a history of (*A*) nausea and vomiting or (*B*) constipation.

in the percentage of follow-up cures occurred in the absence of the history of constipation, 90 per cent as compared to 83 per cent (table 9, chart 5 *B*). No appreciable variations were found according to the degree of inflammation present.

PHYSICAL FINDINGS

One of the most interesting sets of facts appeared in the study of the incidences of microscopic pathologic change according to physical findings and their correlation with the percentages of follow-up cures.

When tenderness was present in sites other than the right lower abdominal quadrant, the incidences of inflammatory changes checked with or approached closest to those found in the absence of symptoms and physical findings (table 11, chart 7). The greatest variations from the standard incidences were found when tenderness was present in the right lower abdominal quadrant with muscular spasm. The remaining groups showed a definite variation from the standard, although not to

TABLE 8.—*Incidence of Inflammatory Change in the Appendix According to a History of Nausea and Vomiting*

	Total Cases	Total without Inflammation	Normal	Atrophie	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard*	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Nausea and vomiting	572	29	25	3.7	71	24	47	7.0	26	9.3	4.2
None†	298	28	23	4.3	72	26	46	4.7	28	10.6	2.7
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

† This classification includes all histories in which nausea and vomiting were said not to have occurred or were not mentioned.

TABLE 9.—*Incidence and Follow-Up Cures According to a History of Constipation*

	Total Cases	Incidence, per Cent	Per Cent Cured
Constipation	362	42	83
None*	519	58	90
Total	881	100	87

* This classification includes all histories in which constipation was said not to have occurred or was not mentioned.

such a marked extent. When tenderness was not present in the abdomen, the patient having been operated on because of the history or the findings in previous attacks, the variation from the standard was least after that of the cases in which tenderness was found elsewhere than in the right lower abdominal quadrant. When tenderness was not detected high on the right by rectal or pelvic examination, the variation from the standard was slightly greater than when it was detected. The one exception was in cases of chronic exudative appendicitis, which might well be expected to produce definite tenderness at times.

The percentages of follow-up cures checked very well with the findings just mentioned (table 12, chart 8). The highest incidence (96 per cent) occurred when tenderness was found in the right lower

TABLE 10.—*Incidence of Inflammatory Change in the Appendix According to a History of Constipation*

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard*	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Constipation	358	31	26	4.8	69	23	46	5.6	28	6.2	3.3
None†	512	27	23	3.3	73	26	47	6.6	26	10.0	3.9
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

† This classification includes all histories in which constipation was said not to have occurred or was not mentioned.

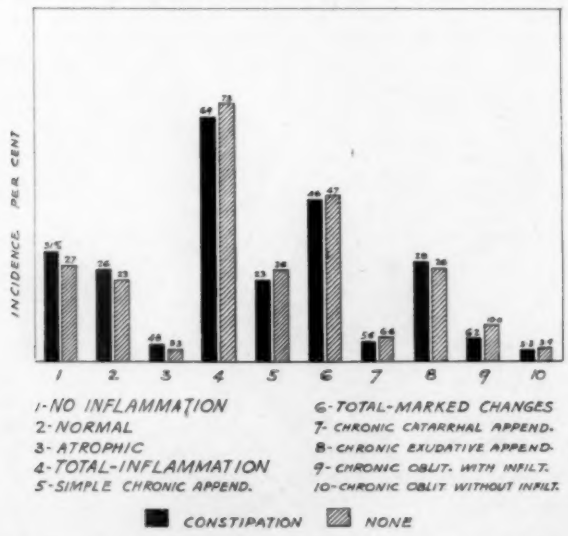

Chart 6.—Incidence of inflammatory changes according to a history of constipation. The incidence is slightly increased in the absence of such a history.

abdominal quadrant associated with muscular spasm. As contrasted to this, when muscular spasm was not present the incidence of cures was 86 per cent, approximately the average for the whole group. No variation was found in the proportion of cures according to whether

tenderness high on the right was or was not detected by rectal or pelvic examination, the figures being 88 and 87 per cent, respectively. The remaining groups were too small to give conclusive figures, but the fact

TABLE 11.—*Incidence of Inflammatory Change in the Appendix According to Physical Findings*

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard*	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Tenderness in the right lower abdominal quadrant without muscular spasm	578	28	24	3.8	72	26	47	6.4	28	9.0	3.5
Tenderness in the right lower abdominal quadrant with muscular spasm	115	23	20	3.5	77	21	56	9.0	34	9.0	5.2
No tenderness in the abdomen	145	32	28	3.6	68	28	41	4.1	21	11.7	4.1
Tenderness high on the right detected by rectal or vaginal examination	155	30	28	2.6	70	26	44	4.5	30	7.1	2.6
No tenderness detected by rectal or vaginal examination	514	26	22	4.1	74	26	48	7.4	25	11.5	3.7
Tenderness elsewhere	72	42	35	7.0	58	20	38	11.1	15	11.1	0.0
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

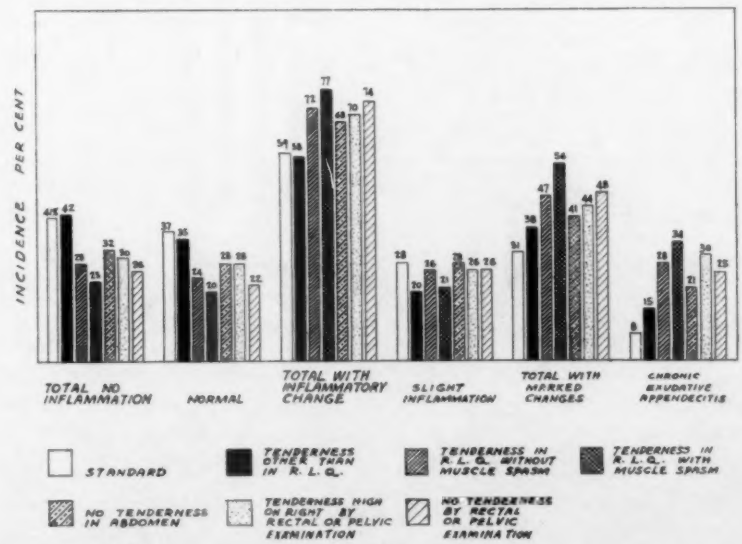
INCIDENCE PER CENT
TOTAL NO INFLAMMATION
NORMAL
TOTAL WITH INFLAMMATORY CHANGE
SLIGHT INFLAMMATION
TOTAL WITH MARKED CHANGES
CHRONIC EXUDATIVE APPENDICITIS
STANDARD
TENDERNESS OTHER THAN IN R. L. Q.
TENDERNESS IN R. L. Q. WITHOUT MUSCLE SPASM
TENDERNESS IN R. L. Q. WITH MUSCLE SPASM
NO TENDERNESS IN ABDOMEN
TENDERNESS HIGH ON RIGHT BY RECTAL OR PELVIC EXAMINATION
NO TENDERNESS BY RECTAL OR PELVIC EXAMINATION

Chart 7.—Incidence of inflammatory changes according to physical findings. Note that the incidences of pathologic changes in cases in which tenderness was found in sites other than the right lower abdominal quadrant approximate very closely those in cases in which the appendixes were removed from patients never suspected of having had appendicitis.

that the incidences were uniformly low and that the total incidences of microscopic pathologic changes checked closely with the incidence found in the absence of symptoms and physical findings (chart 7) would indicate that these figures may be accepted. Physical signs elsewhere than in the right lower abdominal quadrant do not indicate the proba-

TABLE 12.—*Incidence and Follow-Up Cures According to Physical Findings*

	Total Cases	Incidence, per Cent	Per Cent Cured
Tenderness in the right lower abdominal quadrant or McBurney's point without spasm	586	67	86
Tenderness in the right lower abdominal quadrant or McBurney's point with spasm	116	13	96
No tenderness in the abdomen	147	16	87
Tenderness high on the right detected by rectal or pelvic examination	157	18	88
No tenderness detected by rectal or pelvic examination	520	59	87
Tenderness about the umbilicus	9	1.0	83
Tenderness in the left lower abdominal quadrant	3	0.3	67
Tenderness in the right upper abdominal quadrant	16	1.8	50
Tenderness in the entire abdomen	8	0.9	67
Tenderness in the right flank	20	2.3	64
Tenderness in the right costovertebral angle	16	1.8	70
Total	881	100	87

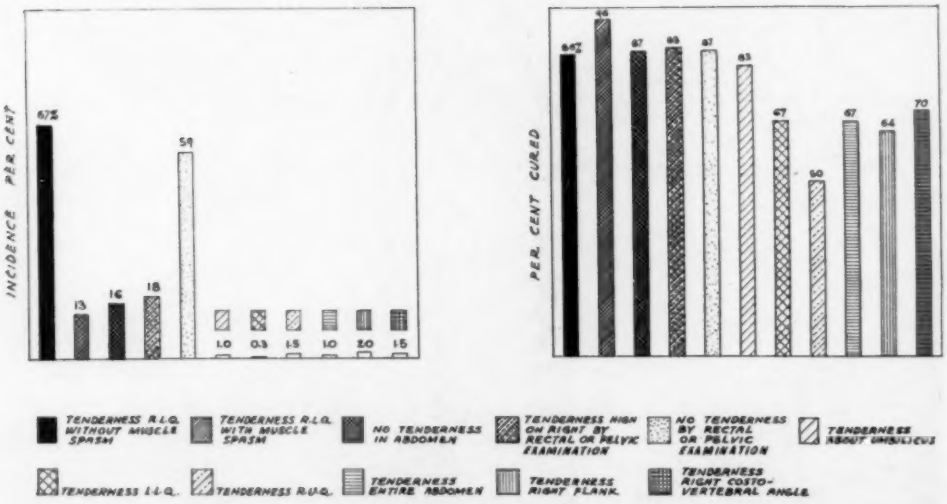

Chart 8.—Incidence and percentages of cures according to physical findings. The percentages of cures are uniformly low in the cases in which tenderness was present in sites other than the right lower abdominal quadrant. This observation checks with the incidences of inflammatory changes (chart 7).

bility of relief by the removal of the appendix. There is one exception, tenderness in the region of the umbilicus, with 83 per cent follow-up cures; but this site is close to the normal location of the appendix, and tenderness there could very well at times be actual appendical tenderness.

LEUKOCYTE COUNTS

When no leukocyte count was done and when the counts were under 10,000 (table 13), the incidences of the various types of pathologic change found in the appendix presented no appreciable variations from the averages. Associated with counts from 10,000 to 12,000 there was

TABLE 13.—*Incidence of Inflammatory Change in the Appendix According to Leukocyte Count* *

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard†	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
No leukocyte count	277	30	25	4.7	70	26	44	5.1	24	10.5	4.0
Leukocyte count under 10,000	319	28	25	3.4	72	25	47	6.3	28	9.4	3.4
Leukocyte count 10,000 to 12,000	116	29	25	4.3	71	19	52	8.6	31	6.9	4.3
Leukocyte count 12,000 to 14,000	78	22	21	1.2	78	29	49	9.0	24	14.1	1.2
Leukocyte count 14,000 and over	80	29	24	5.0	71	30	41	3.7	25	7.5	5.0
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* No outstanding trends are in evidence, although there is a tendency to vary from the incidences found in the absence of symptoms as the leukocyte counts increase up to 14,000. When the count is above this figure, the incidences approach nearer to that which occurs when no pathologic condition of the appendix was suspected preoperatively.

† The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

TABLE 14.—*Incidence and Follow-Up Cures According to Leukocyte Count* *

Leukocyte count	Total Cases	Incidence, per Cent†	Per Cent Cured: Inflammation in Appendix: None	Slight	Marked	Total	Per Cent Cured: Entire Group
Under 10,000	320	54	82	94	90	91	90
10,000 to 12,000	117	19	82	94	92	92	90
12,000 to 14,000	78	13	83	90	90	90	89
14,000 and over	82	14	83	81	96	90	88
Total	597	100‡	82	91	91	91	89

* No relation between the leukocyte counts and follow-up cures can be demonstrated.

† Percentages are based on 597 cases in which leukocyte counts were done.

‡ Of all the cases studied, leukocyte counts were recorded in 68 per cent.

little change from the averages, although a slight increase in the incidences of inflammatory changes was present. This became somewhat more noticeable when the counts were from 12,000 to 14,000. When they were above the latter figure the percentages dropped back to or below the averages. The percentages of follow-up cures held close to the averages throughout (table 14), notwithstanding differences in the leukocyte counts.

PREOPERATIVE DIAGNOSES

The preoperative diagnosis is the surgeon's total impression of the history, the physical examination and the reports from the laboratory. Here it may be considered as a measure of the severity of the symptoms,

TABLE 15.—*Incidence of Inflammatory Change in the Appendix According to Preoperative Diagnosis*

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard*	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Diagnosis of chronic appendicitis	308	33	27	6.5	67	25	42	5.5	23	8.4	4.9
Diagnosis of interval appendectomy	188	31	28	3.2	69	30	38	6.4	17	9.6	5.3
Diagnosis of subacute appendicitis	233	25	23	2.6	75	21	54	6.9	36	9.5	0.9
Diagnosis of acute appendicitis	116	20	18	1.7	80	24	56	6.0	34	12.1	4.3
Other diagnoses	25	16	16	0.0	84	24	60	8.0	36	16.0	0.0
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

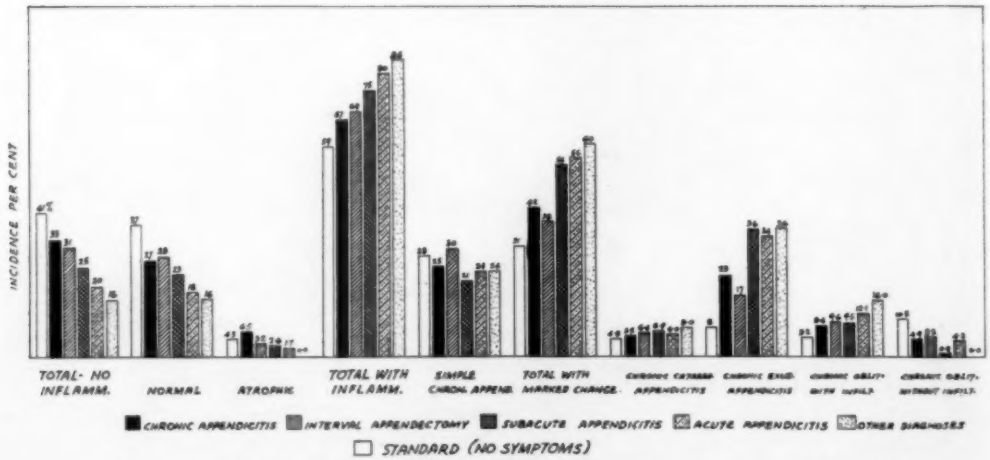

Chart 9.—Incidence of inflammatory changes according to the preoperative diagnosis. The chart demonstrates the fact that the more severe the symptoms and physical findings (as indicated by the preoperative diagnoses), the more the incidences of inflammatory changes vary from those found in cases in which the patients had had no symptoms or physical findings attributed to the appendix. An exception is found in the cases in which other diagnoses than appendicitis were made, but these were cases of patients in the older age groups.

the seriousness of the physical findings and the increase in the leukocyte count, provided the last group, "other diagnoses" (table 15), is temporarily ignored. The incidences of inflammatory changes varied directly, and noticeably, with the severity of the symptoms, etc., as indicated by the preoperative diagnoses (table 15, chart 9). The total incidence of inflammatory changes, the total incidence of marked changes, the incidence of chronic exudative appendicitis and the inci-

TABLE 16.—*Incidence and Follow-Up Cures According to Preoperative Diagnosis*

Diagnosis of	Total Cases	Incidence, per Cent	Per Cent Cured: Inflammation in Appendix: None	Slight	Marked	Total	Entire Group
Chronic appendicitis	309	35	79	91	81	85	82
Interval appendectomy	191	22	84	84	93	89	88
Subacute appendicitis	237	27	80	97	95	96	92
Acute appendicitis	119	13	89	91	94	93	91
Other diagnoses	25	3	86	75	67	69	74
Total	881	100	80	90	89	90	87

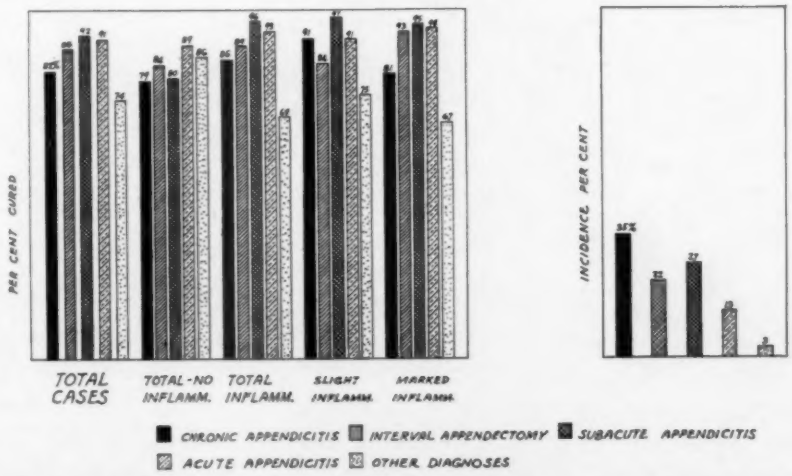

Chart 10.—Percentages of cures and incidence according to the preoperative diagnosis. Throughout, the best percentages of follow-up cures were attained when the diagnosis was subacute or acute appendicitis, and the poorest when some preoperative diagnosis other than appendicitis had been made.

dence of chronic obliterative appendicitis with infiltration increased with the severity of the symptoms as indicated by diagnoses. Incidence in the other groups showed no definite variations in either direction.

In the group of cases classified under the heading "other diagnoses," the number of appendixes studied was too small for the figures to be conclusive. The high incidence of inflammatory changes was due to

the fact that the average age of the patients was past middle life. The effect of age on these incidences will be taken up later in this paper. The distribution of the low percentages of follow-up cures was as uniform as could be expected in view of the small number of cases in this group, 25 (table 16, chart 10). The average, 74 per cent, was by far the lowest proportion of cures found in the various groups as classified according to preoperative diagnoses. This circumstance checked very well with the fact that correspondingly low percentages of follow-up cures resulted when tenderness was found elsewhere than in the right lower quadrant (chart 8). The proportion of cures in the cases in which the diagnosis was chronic appendicitis was somewhat below the average, 82 per cent; in the cases in which the diagnosis indicated interval appendectomy, it was about the average, 88 per cent, and in the cases in which the diagnosis was subacute or acute appendicitis, it was high, 92 and 91 per cent, respectively. The particularly interesting point is that these figures checked with the incidences of inflammatory changes.

TABLE 17.—*Incidence and Follow-Up Cures According to the Wassermann Reaction* *

	Total Cases	Incidence, per Cent	Per Cent Cured
Negative reaction	643	98	88
Positive reaction	16	2.4	100
Total	659†	100	88

* This table is of interest only in that it shows the incidence of positive Wassermann reactions in the series. No evidence of syphilis was found by microscopic examination of the appendixes.

† Wassermann tests were done in 75 per cent of the 881 cases studied.

WASSERMANN REACTIONS

Wassermann reactions were reported in 659 cases, 75 per cent of the total studied. Of these, 16 reactions were positive (table 17), giving an incidence of 2.4 per cent. It is interesting to note that in this small group no patients returned with a recurrence of symptoms. Sections of the appendixes from all of the patients with positive Wassermann reactions were reviewed, and in none could any evidence of syphilitic lesions be found.

SEX

A slight but uniform increase in the incidences of inflammatory changes was found in the appendixes removed from men as compared with those from women (table 18, chart 11 *A*). This information checked with the fact that there was a somewhat higher percentage of follow-up cures in the cases of men, 90 per cent as compared to 86 per cent (table 19, chart 11 *B*). The total number of patients was made up one third of men and two thirds of women.

AGE

The percentages of follow-up cures showed no great variations with increase in the age of the patients (table 20, chart 12). It is of interest,

TABLE 18.—*Incidence of Inflammatory Change in the Appendix According to Sex*

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard*	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Male	285	27	22	5.3	73	23	49	6.6	29	9.8	3.5
Female	585	29	26	3.2	71	26	45	6.0	25	9.6	3.8
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

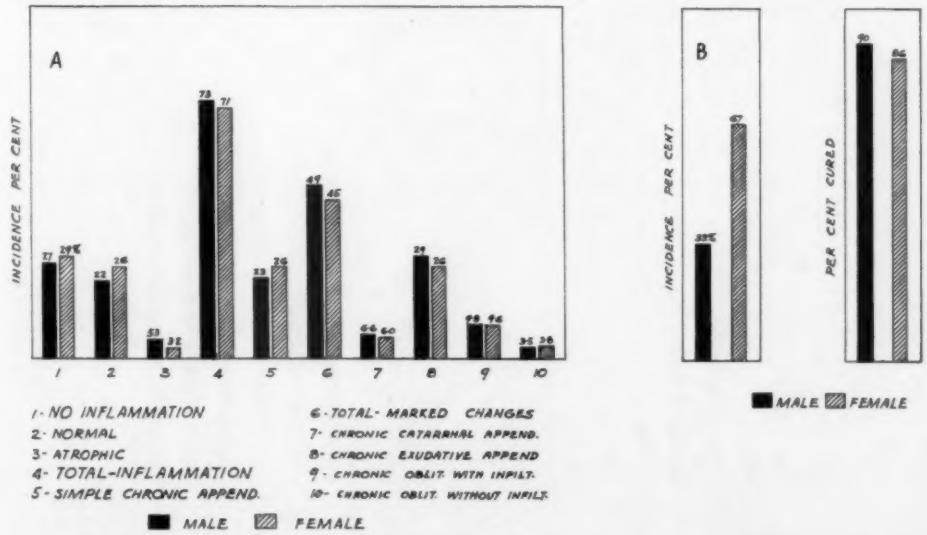

Chart 11.—*A*, incidence of inflammatory changes according to sex. The incidence is slightly higher in the appendixes removed from men. *B*, incidence and percentages of cures according to sex. Corresponding to the increased incidence of inflammatory changes in the appendixes removed from men there is a slight increase in the follow-up cures.

however, to note that the two lowest figures were for the age groups 41 to 50 and 21 to 30 (80 and 84 per cent, respectively). These ages coincide with two periods of physical and mental change in women; i. e.,

the menopause and the period of adjustment to sex and to family or business life. The incidences of inflammatory changes in the appendixes varied with increase in the patients' ages (table 21, chart 13) much as did those in the appendixes which had not been the cause of symptoms or physical findings, but the variations were more marked.

TABLE 19.—*Incidence and Follow-Up Cures According to Sex*

	Total Cases	Incidence, per Cent	Per Cent Cured
Male	289	33	90
Female	592	67	86
Total	881	100	87

TABLE 20.—*Incidence and Follow-Up Cures According to Age*

	Total Cases	Incidence, per Cent	Per Cent Cured
Age 1 to 10	25	3	94
11 to 20	351	40	89
21 to 30	320	36	84
31 to 40	126	14	88
41 to 50	41	5	80
51 to 60	18	2	86
Total	881	100	87

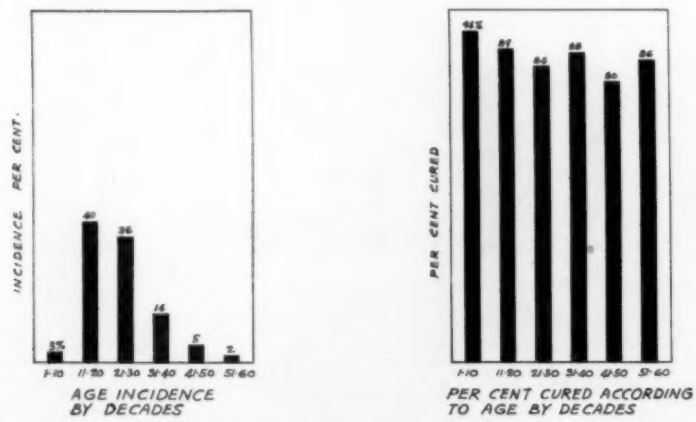

Chart 12.—Incidence and percentages of cures according to age. Seventy-six per cent of the patients were between the ages of 11 and 30. The lowest percentage of follow-up cures is found in the years of the menopause in women. This observation would indicate that in this period of life accurate diagnosis is most difficult.

With increase in the age of the patients, the following changes in incidences appeared: a marked decrease in the incidence of normal appendixes and, in the presence of symptoms, of chronic exudative

TABLE 21.—*Incidence of Inflammatory Change in the Appendix According to Age* *

	Total Cases	Total without Inflammation	Normal	Atrophic	Total with Inflammation	Simple Chronic Appendicitis	Total with Marked Changes	Chronic Catarrhal Appendicitis	Chronic Exudative Appendicitis	Chronic Obliterative Appendicitis with Infiltration	Chronic Obliterative Appendicitis without Infiltration
Standard†	...	41	37	4.3	59	28	31	4.8	8	5.2	10.5
Age 1 to 10	24	33	33	0.0	67	21	46	8.3	38	0.0	0.0
11 to 20	349	34	30	3.7	66	25	42	4.9	28	6.9	1.5
21 to 30	315	30	26	3.8	70	24	46	5.7	26	10.8	3.2
31 to 40	125	17	12	5.0	83	24	59	8.0	28	13.6	8.9
41 to 50	40	15	8	7.4	85	27	58	10.0	20	17.5	10.0
51 to 60	17	6	6	0.0	94	29	65	17.7	24	11.8	11.8
Total	870	28	24	3.9	72	24	47	6.2	27	9.7	3.7

* The trends indicated in this table are much better shown in chart 13.
† The incidence in cases which involve no history or physical findings indicating disease in the appendix is regarded as standard.

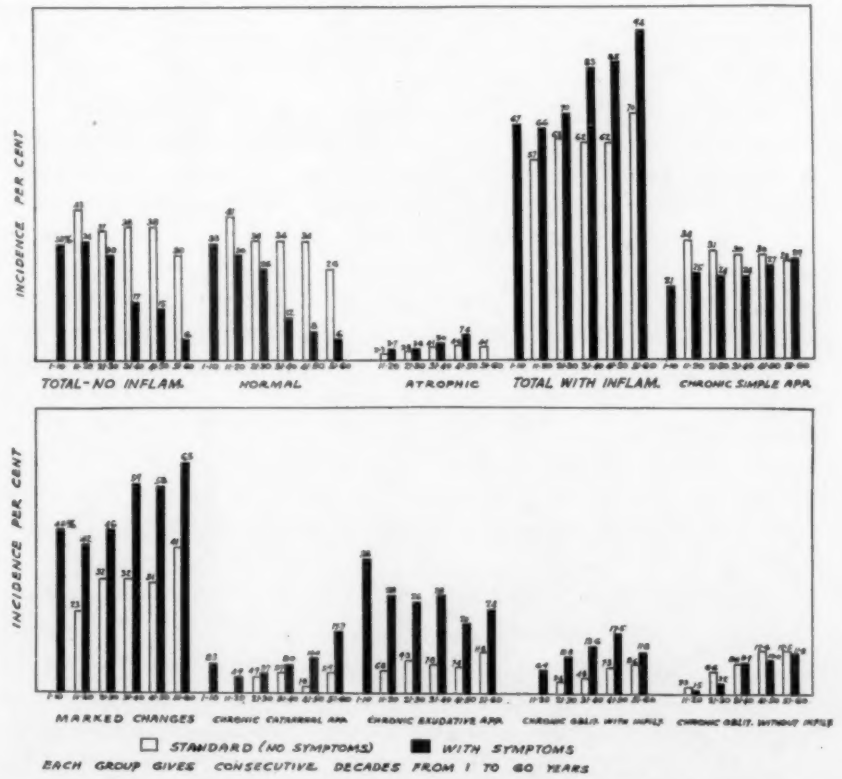

Chart 13.—Incidence of inflammatory changes according to age in the presence and in the absence of symptoms. This chart demonstrates the marked accentuation of the effect of age on the inflammatory changes in the appendix when symptoms are present. This statement does not hold true of simple chronic appendicitis, perhaps because the recurring attacks cause more advanced pathologic changes to appear.

appendicitis, though the latter in the absence of symptoms showed no definite trend; a marked increase in the incidence of atrophic appendixes, chronic catarrhal appendicitis and chronic obliterative appendicitis with and without infiltration, and no marked change in simple chronic appendicitis, although a slight increase was found in the presence of symptoms, whereas a slight decrease occurred in the absence of symptoms. Subacute appendicitis, which pathologically closely approximates chronic exudative appendicitis, also decreases in incidence with increase in the age of the patients.

PATHOLOGIC CONDITIONS OTHER THAN NONSPECIFIC INFLAMMATION

Adhesions and Fecaliths.—A detailed discussion of adhesions and fecaliths was given in connection with tables 3 and 4. Since their incidences were not noted in the absence of symptoms and physical findings attributable to the appendix, no comparisons can be made.

Foreign Body in the Lumen of the Appendix.—Foreign bodies were found 12 times, an incidence of 1.4 per cent, as compared with 0.2 per cent in the absence of symptoms and physical findings.

Oxyuris was noted in 10 appendixes, an incidence of 1.1 per cent, as compared with 0.2 per cent when a pathologic condition of the appendix was not suspected preoperatively. The microscopic examination showed a normal appendix in 1 case, simple chronic appendicitis in 3 and chronic exudative appendicitis in 6. Adhesions were present in 3 cases and fecaliths in 2. The appendix was removed in the first attack in 7 cases, while in the remaining 3 intermittent attacks had occurred for from three to six months. All of the patients presented tenderness at McBurney's point, but only 2 had definite muscular spasm. The total leukocyte counts varied between 7,300 and 22,500 and the differential counts from 74 per cent polymorphonuclears and 26 per cent lymphocytes to 88 per cent polymorphonuclears and 12 per cent lymphocytes. No eosinophils were found in any of the 10. Eight patients were followed, and none had a return of the preoperative symptoms.

A small piece of wire was found in 1 appendix. Microscopically, the pathologic condition was chronic exudative appendicitis. The patient had had continuous pain in the right lower abdominal quadrant for the three months preceding the operation. Tenderness was present at McBurney's point without muscular spasm. The total leukocyte count was 9,000, with 62 per cent polymorphonuclears, 26 per cent lymphocytes, 10 per cent eosinophils and 2 per cent basophils. There were no adhesions about the appendix, but it contained a fecalith. This patient was the only one in the series presenting definite eosinophilia. She had no return of the preoperative symptoms.

A seed was present in one appendix. The patient had had three attacks of pain in the right lower abdominal quadrant in the five months preceding the operation. Tenderness was present at McBurney's point

TABLE 22.—*Incidence and Follow-Up Cures According to Pathologic Condition Other than Nonspecific Inflammation*

	Total Appendixes	Incidence, per Cent*	Standard Incidence†	Per Cent Cured‡
Adhesions§	430	48	...	89
Fecaliths§	156	18	...	89
Foreign body in the lumen	12	1.4	0.2	100
Oxyuris	10	1.1	0.2	100
Wire	1	0.1	0.0	100
Seed	1	0.1	0.0	100
Mucocele	2	0.2	0.2	100
Diverticulum	2	0.2	0.1	100
Lymphoid hyperplasia	1	0.1	0.0	...‖
Tuberculosis	2	0.2	0.3	100
Tumors	7	0.8	0.3	100
Carcinoid	6	0.7	0.1	100
Carcinoma	1	0.1	0.1	100
Total	612	69	1.5	89

* Percentages are based on the 881 cases studied.

† The incidence in cases which involved no history or physical findings indicating disease in the appendix is regarded as standard.

‡ The percentages of follow-up cures hold uniformly high in the presence of these various pathologic conditions.

§ Both adhesions and fecaliths were present in 99 cases.

‖ No follow-up was made in this case.

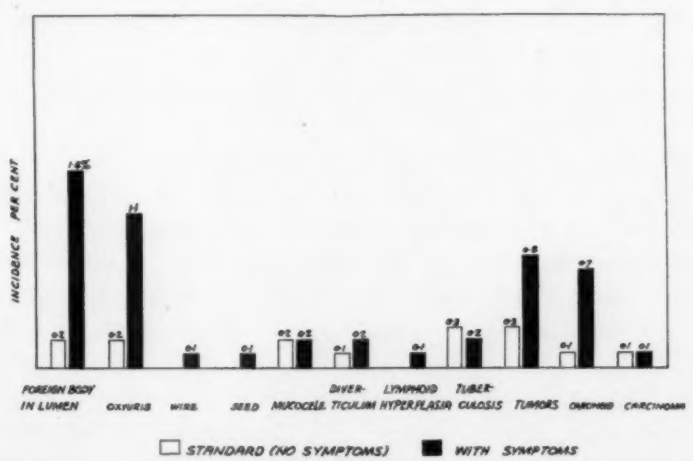

Chart 14.—Comparison of the incidence of pathologic conditions other than nonspecific inflammatory changes in the presence and in the absence of symptoms. With foreign bodies in the lumen of the appendix and with tumors, the incidences are markedly increased in the presence of symptoms referable to the appendix.

with muscular spasm. Adhesions were found about the appendix. Microscopic examination showed only simple chronic appendicitis. This patient had no postoperative return of symptoms.

Mucocele of the Appendix.—Mucocele was found twice, an incidence of 0.2 per cent, which is the same as that found when no symptoms or physical findings indicated a pathologic process in the appendix. One of the patients had had recurrent attacks of pain in the right side of the abdomen for ten years; the other was operated on in the first attack. One presented a normal abdomen; the other, tenderness at McBurney's point without muscular spasm. A leukocyte count done on 1 gave the following results: The total count was 10,000, with 66 per cent polymorphonuclears and 34 per cent lymphocytes. Both patients were followed, and neither had a recurrence of symptoms.

Diverticulum of the Appendix.—Two appendixes showed diverticula, an incidence of 0.2 per cent, as compared with 0.1 per cent when no symptoms were noted. Both patients had had recurrent attacks of pain in the right lower abdominal quadrant, 1 for five months and the other for eighteen months. Both had tenderness at McBurney's point without muscular spasm. No leukocyte counts were made. In each case the uninvolved part of the appendix showed chronic exudative inflammation. Both patients were followed, and no recurrence of symptoms occurred.

Lymphoid Hyperplasia.—Only 1 case of lymphoid hyperplasia was found, an incidence of 0.1 per cent. The patient had had recurrent attacks of pain in the right lower abdominal quadrant for one year. Tenderness was present at McBurney's point without muscular spasm. No adhesions were present. The patient did not return to the follow-up clinic.

Tuberculosis of the Appendix.—Two appendixes were tuberculous, an incidence of 0.2 per cent, as compared with 0.3 per cent when no symptoms or physical findings referable to the appendix were noted. The higher percentage in the latter group may be due to the fact that among the tuberculous appendixes removed at incidental appendectomies were several removed at operations for some other tuberculous condition in the abdomen. One of the patients was operated on in the first attack, the other having had recurrent attacks for three months. Tenderness was present at McBurney's point with muscular spasm in both cases. The leukocyte count of the patient in the first attack was 19,300, with 88 per cent polymorphonuclears and 12 per cent lymphocytes; that of the patient with recurrent attacks was 8,100, with 68 per cent polymorphonuclears and 32 per cent lymphocytes. Pathologically, both appendixes showed chronic tuberculous appendicitis. Neither patient had any return of the abdominal symptoms, although both had continued activity of the pulmonary lesions.

Tumor of the Appendix.—Tumor was found in 7 appendixes, an incidence of 0.8 per cent, as compared with 0.3 per cent in the absence of symptoms or physical findings pointing to a pathologic condition in the appendix.

A carcinoid of the appendix was noted 6 times. Two of the patients were operated on in their first attacks of pain in the right lower abdominal quadrant, the others having had recurrent attacks, 3 for one year or less and the other for many years. The leukocyte counts varied from 7,000 to 18,000 and the differential counts from 76 per cent polymorphonuclears and 24 per cent lymphocytes to 82 per cent polymorphonuclears and 18 per cent lymphocytes. Two patients had normal abdomens, while 4 had tenderness at McBurney's point, of whom 2 had definite muscular spasm. The entire appendix was involved in 1 case. Microscopic examination in the others showed, in the remainder of the appendix, normal conditions in 2 cases, simple chronic appendicitis in 1, chronic obliterative appendicitis in 1 and adhesions in 1. Five patients were followed, of whom none had any return of the symptoms.

TABLE 23.—*Postoperative Deaths* *

Cause of Death	Time Postoperative
Respiratory failure, pulmonary edema	30 minutes
Peritonitis due to Streptococcus haemolyticus†	7 days
Pulmonary embolus	11 days
Acute infection of the upper part of the respiratory tract, purpura haemorrhagica, acute pericarditis, chronic fibrous pleuritis	62 days

* The total number of deaths was 4, a mortality of 0.45 per cent.
† The incidence of peritonitis for the 881 operations was 0.1 per cent.

A carcinoma of the appendix (infiltrating type) was found in 1 case. The appendix contained a fecalith, but there were no adhesions about it. The patient had had recurrent attacks of pain in the right lower abdominal quadrant for two and one-half years, the last having occurred six weeks before the operation. The abdomen was normal on physical examination. After the operation there was no return of the preoperative symptoms and no evidence of recurrence of the malignant growth up to the time when the patient was last seen, more than one year later.

POSTOPERATIVE DEATHS

Four deaths occurred postoperatively in the 881 cases, a mortality of 0.45 per cent. One patient died thirty minutes after operation of respiratory failure. Autopsy revealed only pulmonary edema. This patient had had recurrent attacks of pain in the right lower abdominal quadrant for two years, four in the two weeks before admission. At the time of entrance to the hospital the leukocyte count was 12,000, with 78 per cent polymorphonuclears, 20 per cent lymphocytes and

2 per cent eosinophils. Three days later the count was 8,000, with 76 per cent polymorphonuclears and 24 per cent lymphocytes. The operation was done two days after that. The appendix was bound down and kinked in the middle by adhesions. Microscopically, it showed chronic obliterative appendicitis.

A second patient died seven days after operation of peritonitis due to Streptococcus haemolyticus. At autopsy the region of the cecum was found to be normal. This patient had had two attacks of pain in the right lower abdominal quadrant, the first a year and the second six weeks before the operation. The appendix was found kinked in the middle by adhesions and was microscopically normal.

Two other patients died after leaving the surgical service. One died of pulmonary embolus on the eleventh day after operation, two days after leaving the hospital. This patient had had recurrent attacks of pain in the right lower abdominal quadrant for six years, the last occurring ten days before admission. The leukocyte count was 10,500, with 78 per cent polymorphonuclears and 22 per cent lymphocytes. The appendix was kinked by adhesions and microscopically showed chronic obliterative appendicitis with infiltration.

The last fatality was in the case of a patient who died two months after operation, while under treatment in the medical service. Up to the eleventh day after operation her convalescence was uneventful. An acute sore throat then developed, with infection in the ethmoid sinuses and antrums. The diagnosis during the illness, confirmed at autopsy, was purpura haemorrhagica, acute pericarditis and chronic fibrous pleuritis. On admission the patient had given a history of attacks of pain in the right lower abdominal quadrant for six months, the last having been present at the time of admission. Examination of the abdomen showed tenderness at McBurney's point without muscular spasm. The leukocyte count was 10,000, with 80 per cent polymorphonuclears and 20 per cent lymphocytes. The appendix was bound down by adhesions and appeared edematous. Microscopically, it showed a marked chronic exudative appendicitis. During the two months of her postoperative illness the patient had no attacks of pain in the right lower abdominal quadrant. It might well be considered that this last case should not be included in the calculation of postoperative mortality.

SUMMARY

A critical study has been made of 881 cases in which appendectomy was performed because of symptoms attributed, either before or after the operation, to a nonspecific chronic inflammation in the appendix. The microscopic observations in these appendixes were compared with a standard, the incidences of microscopic pathologic conditions when

there were no symptoms or physical findings attributable to the appendix and no inflammation noted elsewhere in the abdomen. A considerable increase in inflammatory changes was found, due entirely to the marked increase in the incidences of chronic exudative appendicitis and chronic obliterative appendicitis with infiltration. A corresponding decrease in the incidence of normal appendixes occurred.

The percentages of follow-up cures were found to be low when no inflammatory changes were present, cases involving atrophic appendixes giving the lowest figure. When inflammatory changes were found, a higher percentage of follow-up cures resulted from appendectomy. These cures appeared not to depend on the type of inflammatory change present or its variation from the standard incidence as described. When adhesions or fecaliths were found with a normal appendix, the percentage of follow-up cures was increased almost to those found when inflammatory changes were present in the appendix.

When the patients gave a history of more than one attack occurring within a period of one year or less, the percentage of follow-up cures was remarkably high. It was low when the attacks covered a period longer than one year and was still lower when the patients were operated on during or following the first attack. The incidences of inflammatory changes were unaffected by the presence or absence of a history of nausea and vomiting, although the percentage of follow-up cures was slightly decreased in the presence of such a history. When a history of constipation was given, the incidences of inflammatory changes decreased slightly, as did the percentage of follow-up cures.

Both the incidences of inflammatory changes and the percentages of follow-up cures varied directly with the definiteness of localization and the seriousness of the physical findings in the right lower abdominal quadrant, the highest figures being obtained when both tenderness and muscular spasm were present. When tenderness was found elsewhere in the abdomen than in the right lower quadrant, the incidences of inflammatory changes checked almost exactly with those for the patients who had had no symptoms or physical findings referable to the appendix and the lowest percentages of follow-up cures resulted. When the patients were operated on only because of the history of attacks of pain in the right lower abdominal quadrant, no tenderness having been found after admission to the hospital, the results were the same as the average for the whole group studied. The presence or absence of tenderness high on the right detected by rectal or vaginal examination bore no apparent relation to the incidences of inflammatory changes or to the percentages of follow-up cures.

The leukocyte counts did not appear to bear a definite relation to the follow-up cures or to the incidences of pathologic change, although with a moderate increase in the leukocyte counts there was a slight

increase in the incidences of inflammatory changes. The incidences of inflammatory changes in the appendix were found to vary directly with the definiteness of the localization and the severity of the patient's symptoms as indicated by the diagnoses. This relation was corroborated by an equivalent increase in the follow-up cures in the same sequence. When diagnoses other than appendicitis were made preoperatively and the symptoms attributed to the appendix after operation, the percentage of follow-up cures was low notwithstanding a high incidence of inflammatory changes. (The average age of these patients was much higher than that in the other groups.) This finding checked with the equally low percentages of follow-up cures when tenderness had been noted elsewhere in the abdomen than in the right lower quadrant.

The incidence of positive Wassermann reactions was 2.4 per cent. This condition bore no demonstrable relation to either the pathologic condition of the appendix or the follow-up cures. The ratio of men to women was 1:2, with a slight increase in the incidences of inflammatory changes and percentage of follow-up cures in the men. With an increase in the age of the patients there was a marked increase in the incidences of atrophic appendixes, chronic catarrhal appendicitis and chronic obliterative appendicitis with and without infiltration; no definite change occurred in the incidences of simple chronic appendicitis and chronic exudative appendicitis, and a marked decrease took place in the incidences of normal appendixes. The changes with increase in the age of the patients were much greater than in the appendixes from patients who had not been suspected preoperatively of ever having had any appendical pathologic condition. Even after the small number of appendixes presenting pathologic changes other than inflammatory changes was taken into account, the figures did show that these conditions increased in incidence in the presence of symptoms and physical findings attributed to the appendix and that appendectomy did give relief from those symptoms.

CONCLUSIONS

1. A chronic inflammatory process, adhesions, fecaliths or combinations of these conditions in the appendix have been shown to be the cause of definite symptoms and physical findings which can be relieved by appendectomy. A general term "chronic appendicitis" is suggested to cover these conditions.

2. In properly selected cases, an appendectomy for chronic appendicitis gives an excellent expectation of cure, but the following points should be borne in mind: (*a*) In the presence of a history of nausea and vomiting or of constipation, especially in women, particular care must be exercised in the selection of cases. (*b*) The more definite and

localized the physical findings, the better is the expectation of cure. When tenderness is found in other parts of the abdomen than the right lower quadrant, one should be most reluctant to attribute the patient's symptoms to chronic appendicitis. (*d*) The expectation of cure is excellent when the history is of more than one attack within a period of one year or less, much poorer when the attacks cover a period longer than one year and poorest when the patient is operated on in or following the first attack.

3. When no inflammatory change is found in the appendix, the expectation of cure is not good unless either adhesions or fecaliths are present, in which case the results are nearly equal to those obtained when inflammatory changes are present.

4. Owing to recurrent attacks, there is evidently an increase in the pathologic condition in the appendix, as the change with age is much more marked than in the absence of symptoms attributable to the appendix.

5. A mortality of less than 0.5 per cent in the 881 appendectomies would indicate that the operation for the cure of chronic appendicitis is a safe procedure.

6. Incidentally, it has been shown that when a patient has been operated on because of symptoms and physical findings diagnostic of acute or subacute appendicitis and, instead, one of the types of chronic appendicitis (or adhesions or fecaliths without inflammation) is found, the expectation of a permanent cure is excellent. Ordinarily the surgeon lists these as mistaken diagnoses, but the figures as to the marked increase of the incidences of inflammatory changes above those when no symptoms had been attributed to the appendix and the high percentages of follow-up cures found in this study would indicate that the surgeon under such circumstances has benefited the patient almost as much as though acute appendicitis had been found.

One must bear in mind that before operating on any patient for chronic appendicitis because of the conclusions arrived at in this paper, the utmost in diagnostic acumen must be exercised in ruling out all conditions which give a picture simulating that presented by chronic appendicitis. The question of differential diagnosis was outside the limitations of this paper and can be considered only after one has established the fact that there is definitely such a clinical entity as chronic appendicitis.

The pathologic examinations of all the appendixes in this and the preceding study were made by Dr. Leila C. Knox.

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SUBACUTE INFECTIONS OF BONE

OSTEOPERIOSTITIS ALBUMINOSA OLLIER

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Some years ago there came under my observation a case of superficial osseous destruction—osteoperiostitis—showing peculiar clinical and anatomic characteristics as well as diagnostic difficulties (case 1). During the winter of 1935 a second case presented itself, with a strikingly similar history, clinical course, roentgenographic appearance and pathologic condition (case 2). These were obviously cases of bony infection by attenuated organisms of low virulence (staphylococci). The infection was indolent from its beginning and at no time caused the usual local or general acute symptoms. It was in many ways different from other acute and subacute forms of osseous infection, especially from those described by Brodie and Garré. Since these 2 cases were observed, 2 others with similar characteristics have presented themselves.

The condition corresponds to that described in medical literature as "osteoperiostitis albuminosa." It is not mentioned in the usual standard works on surgery or pathology, and reference is made to it only occasionally in the general American literature. Even then it is chiefly noticed in connection with the etiology of bony cysts. For years it has claimed the lively interest of French and German observers. Ollier was the first to note the condition (1864), and at his behest a second case was reported by his pupil Poncet [1] in 1874. Since that time accounts of new cases have slowly trickled into the general literature, so that the reported cases now number around 66. The first report of an American case was made by Dupuis [2] in 1889. The only other cases reported in the American literature are those reviewed by Pickrell and Schmidt [3] in 1910 and Hartwell [4] in 1911. Most writers, even the most recent, have stressed the rarity of the condition. During the past seventy years the clinical picture of the disease has come to be well defined in

1. Poncet, M. A.: De la périostite albumineuse, Gaz. hebd. de méd. **11**:133 (Feb.); 179 (March) 1874.

2. Dupuis, T. R.: A Case of Periostitis Albuminosa of Ollier, Canada Lancet **21**:357 (Aug.) 1889.

3. Pickrell, G., and Schmidt, L. M.: Chronic Nonsuppurative Osteoplastic Periostitis of Traumatic Origin, U. S. Nav. M. Bull. **4**:1 (Jan.) 1910.

4. Hartwell, J. A.: Periostitis Albuminosa, Proc. New York Path. Soc. **10**: 55, 1910-1911.

all its phases. It is essentially that of a localized, indolent swelling consisting of periosteal, subperiosteal, parosteal or intermuscular accumulations of clear, serous, stringy or mucoid exudate. This exudate often resembles the white of an egg or synovial fluid.[5] It has a high albumin content, is frequently encapsulated and on culture may show the presence of ordinary pus organisms (staphylococci). The usual symptoms of infection are absent. An analogue is a form of osseous cyst showing similar characteristics which because of its benign course may develop over years.

REVIEW OF THE LITERATURE[6]

In reviewing the available literature, I was able to trace 66 cases reported between 1864 and 1934. While this review was in preparation, allusion was made in the more recent literature to 4 or 5 other cases, but these have not been available for inclusion. In the reports of some cases many data of importance are missing, but most of them are fairly complete in essentials.

Incidence.—Of the reported cases in which sex was indicated, 51 were those of men or boys and 10 of women or girls. In 4 cases the age was given as "young"; in 2 it was not mentioned. Eight patients were in the first decade of life, 26 in the second, 12 in the third, 9 in the fourth, 6 in the fifth, 3 in the sixth and 1 (a woman aged 79) in the eighth. The femur was involved in 33 cases (the distal end in 19, the middle third in 8 and the proximal end in 6), the tibia in 21 (the distal end in 8, the middle third in 2 and the proximal end in 9), the humerus in 5 (the distal end in 2 and the proximal end in 2), the ulna in 4 (the distal end in 1, the middle third in 1 and the proximal end in 2), the radius in 1, the phalanges of the fingers in 2, the ilium in 4, a rib in 1 and the skull in 1. There were 4 cases in each of which two bones were involved: femur and rib, femur and humerus, tibia and ulna, and tibia and humerus.

Duration.—The duration of symptoms previous to the time of observation was noted as follows: from four days to one month in 12 cases, from one to two months in 9, from three months to one year in 13, from one to two years in 10, five years in 1 and from ten to twenty-nine years in 6.

5. Poncet (1874): "Une forme spéciale de périostite non décrite jusqu'ici, caractérisée anatomiquement par l'accumulation sous le périoste et dans les couches périostales d'un liquide visqueux, analogue à la synovie. . . . Ajoutons la presence fréquente pour certaines formes de gouttelettes de graisse en plus ou moins grande abondance, rappelant le bouillon gras. . . . le liquide n'est pas toujours visqueux, analogue à du blanc d'œuf. M. Ollier a trouvé une fois entre autres au fémur un liquide séreux, non filant mais clair, avec quelques gouttelettes huileuses."

6. Miss Gladys Ramsey, librarian at the University of Wisconsin, aided in collecting for study the widely scattered sources.

The Exudate.—The disease was identified in the reported cases only after aspiration or incision. In 32 cases the fluid removed was described as serous and stringy (yellow, clear yellow, serous and purulent in 1 each), in 11 as jelly-like, in 17 as serosanguineous (resembling jelly in 5 and purulent in 1), in 1 as resembling glycerine, in 2 as clear, and in 1 as milky white. Ollier [7] (1874) pointed out that the fluid on standing tended to separate into three layers, a bottom layer consisting of broken clumps and flakes with red and white blood cells, a middle clear serous layer and a top layer of floating particles of fat. Riedinger [8] (1887) observed mucin and albumin—a slimy, jelly-like fluid containing "animal gum"—and, microscopically, occasional white blood cells. Schlange [9] (1887) reported albumin, paralbumin, metalbumin, phosphates, carbonates and large amounts of sugar (with absence of sugar in the urine), fat and, microscopically, red and white blood cells with occasional fat cells. Schrank [10] (1893) saw many fat globules and yellow flakes. Microscopically he noted clots of fibrin with red and white blood cells and many small droplets of fat and cells in fatty degeneration (*Fettkörnchenzellen*).

Jacoby [11] (1897) noted the presence of small gelatinous clumps. He recorded a chemical analysis of the characteristic exudate as follows: alkaline reaction; water, 91.61 per cent, and solids, 8.39 per cent (nucleoalbumin, 0.87 per cent; serum albumin, 5.61 per cent; fat and extractives, 0.98 per cent, and mineral salts, 0.93 per cent). He drew attention to the resemblance of the fluid to that found in hydrarthrosis. Rondot [12] (1903) also compared the fluid to that of hydrarthrosis. He described it as follows: specific gravity, 1.026 (at 15 C.); albumin, 55 Gm. per thousand cubic centimeters; no fibrin but a few leukocytes and altered red blood cells. In a second case Rondot noted crystals of cholesterol, leukocytes and a few threads of fibrin; in another case he likened the exudate to the effusion of pleurisy. Scheidler [13] (1910) in 2 cases noted red and white blood cells, large cells with fatty degeneration and many droplets of fat. Hartwell [4] (1910) in 1 case noted

7. Ollier, cited by Poncet.[1]

8. Riedinger, F.: Ueber Ganglion periosteale, in Festschrift, Albert von Kölliker zur Feier seines siebenzigsten Geburtstages, gewidment von seinen Schülern, Leipzig, 1887.

9. Schlange: Ueber einige seltenere Knochenaffectionen, Arch. f. klin. Chir. **36**:97, 1887.

10. Schrank, W.: Periostitis albuminosa, Arch. f. klin. Chir. **46**:724, 1893.

11. Jacoby, E.: Ein Fall von Periostitis albuminosa, Inaug. Dissert., Bonn, Carl Georgi, 1897.

12. Rondot, A.: La périostite albumineuse, Thesis, Lyon, no. 125, 1903.

13. Scheidler, F.: Zur Periostitis albuminosa (Ollier), Beitr. z. klin. Chir. **68**: 480, 1910.

a clear yellow, thick, gelatinous exudate, rich in plasma cells; in a case with similar exudate, he observed that the fluid contained "pus detritus." He stated that the exudate is often free from cellular elements, contains a high percentage of protein, frequently up to 3 per cent, and often coagulates spontaneously. The tendency to coagulate apparently depends on the presence of leukocytes containing prothrombin. Burckhardt [14] (1911), examining 2 liters of fluid in 1 case, observed that it separated into a light, serous part and a "vitreous" part containing tags and membrane. Mazzini [15] (1932) and many observers before him likened the fluid to synovia. Stropeni [16] (1933) described the fluid as amber colored, stringy and like the white of an egg. Moulonguet and Rousset [17] (1934) noted in 1 case a sticky, "gluey" liquid (1 liter) with a reddish tint and many clots of fibrin. In a second case they saw only a few cubic centimeters of bloody liquid within a large, thick sac. Battle [18] (1904) reported a fluid resembling milk.

Bacteriologic Observations.—Schlange [9] (1887), the first to report the results of bacterial examination of these exudates, obtained a growth of Staphylococcus aureus in 1 case and a negative culture in another. Negative cultures have been reported in 6 cases. Positive cultures have been reported as follows: Staph. aureus in 11 cases, Staphylococcus albus in 2 and Staphylococcus without further specification in 2. Lexer [19] (1898) found streptococci in the case of a child 9 weeks old. Burckhardt [14] (1911) observed in sections a small chain of three or four cocci but obtained no culture. Schrank [10] (1893) in 1 case [20] found many

14. Burckhardt, J. L.: Zur Histologie der Periostitis und Ostitis albuminosa, Frankfurt. Ztschr. f. Path. **8**:91, 1911.

15. Mazzini, O. F.: Periostitis albuminosa, Bol. y trab. de la Soc. de cir. de Buenos Aires **16**:164 (April) 1932.

16. Stropeni, L.: Periostitis albuminosa, Boll. e mem. Soc. piemontese di chir. **3**:315 (March) 1933.

17. Moulonguet, P., and Rousset, J.: Les abscès ossifluents chroniques à staphylocoque (périostite albumineuse d'Ollier et Poncet), J. de chir. **44**:161 (Aug.) 1934.

18. Battle, W. H.: The Diagnosis of Osteosarcoma of the Long Bones, Lancet **2**:582, 1904.

19. Lexer, E.: Zur Kenntnis der streptokokken- und pneumokokken-Osteomyelitis, Arch. f. klin. Chir. **57**:884, 1898.

20. His case 2, that of a boy 14 years of age with a previous history of typhoid fever and osteitis some years before. For six weeks swelling of the inner malleolus of the right tibia with abundant, bloody, serous, nontenacious fluid, containing small whitish yellow flakes and many fat globules. At operation a small area of the periosteum was seen to be destroyed, but the underlying bone was not necrotic. Destruction of the periosteum had left a small cavity, the walls of which were covered with soft golden yellow granulations. Low in the cavity a small fistula led to a small bony focus with an abscess containing creamy pus and a small sequestrum. This cavity also was lined with the yellow granulations (color plate, *24*).

streptococci and an occasional staphylococcus, the latter predominating in the osteomyelitic pus. L. Dor [21] (1895) reported observing in a collection of parosteal serous fluid a polymorphous organism with colonies of lemon yellow, the consistency of wax, which slowly liquefied gelatin. He named it Bacillus cereus citreus. By intravenous injection of a pure culture of this organism into rabbits, he caused in 1 animal nonsuppurative infectious osteitis, which produced a large exostosis. In another animal he brought about typical periostitis albuminosa. Garré [22] (1891) inoculated rabbits with staphylococci from a patient with periostitis albuminosa without producing ill effects. Inoculation with pus from ordinary osteomyelitis, on the other hand, caused the usual signs and lesions of the infection. It was necessary to use large amounts of fluid from periostitis albuminosa to obtain a culture of staphylococci.

Mazzini [15] (1932), in a typical case of periostitis albuminosa, noted, on culture of the gelatinous, stringy, transparent fluid, a gram-positive diplococcus, which grew slowly. Inoculation with the culture produced no local lesion in a guinea pig. A second culture, made several weeks later, at the time of operation, showed no growth. A guinea pig inoculated with the exudate showed no lesion of any kind when killed after two months. Stropeni [16] (1933) on inoculation of a rabbit with a culture of Staph. albus made from the exudate in a case of periostitis albuminosa observed a chronic septicemia with many abscesses. There was no local reaction; a curdlike pus was noted, but no bony lesions occurred. In some of the recorded cases, especially the earlier ones, reported by Lannelongue, Nicaise,[23] Rondot [12] and others, there is a strong suspicion that the lesions were tuberculous. Breuer [24] (1893) and Sleeswijk [25] (1894) described cases in which the condition clinically resembled periostitis albuminosa but was generalized and undoubtedly tuberculous. In Sleeswijk's case the tuberculous character of the symptoms was proved by inoculating the exudate into a rabbit. (Cases of Breuer, Sleeswijk and others in which the tuberculous nature of the disease was unquestioned are not included in the series here reviewed.)

21. Dor, L.: Contribution à l'étude de la périostite albumineuse, des hyperostoses et des exostoses infectieuses, Arch. prov. de chir. **4**:13, 1895.

22. Garré, C.: Einige seltenere Erscheinungsformen der acuten, infektiösen Osteomyelitis, in Festschrift zum fünfundzwanzigjährigen Doktor- und Dozenten-Jubiläum von Theodor Kocher, Wiesbaden, 1891.

23. Nicaise, cited by Bar, E.: De la pathogénie de la périostite albumineuse ou séreuse et d'un nouvel agent pathogène de cette affection, Thesis, Lyon, no. 1017, 1894.

24. Breuer, F.: Ueber sogenannte seröse Abscesse, Inaug. Dissert., Berlin, Emil Ebering, 1893.

25. Sleeswijk, R.: Ueber die sogenannte Periostitis albuminosa (Ollier), Inaug. Dissert. (Jena), Amsterdam, J. A. Sleeswijk, 1894.

Pathologic Process.—The earlier observers described the chief changes brought about by periostitis albuminosa as taking place in the periosteum. The collections of exudate have been reported as arising subperiosteally, intraperiosteally and extraperiosteally. They have been seen free in the soft tissues, with no definite encapsulation, and have been seen enclosed in a more or less definitely formed sac. At times the exudate is described as infiltrating the periosteum, muscles and fascia, changing these structures into a succulent, soggy mass (*épanchement, Flüssigedurchtränkung*). Cases have been reported in which the exudate was associated with no demonstrable lesion of the neighboring bone. Other cases in which the periosteal changes and the exudate were secondary to osteitis and osteomyelitis are included in the literature. The existence of two separate lesions in close proximity has occasionally been described.[20] Schlange [9] was the first to draw attention to the association of the disease with osseous lesions, and because of these lesions he proposed the name "osteomyelitis non purulenta." The color plate represents an attempt to classify and illustrate diagrammatically the various pathologicoanatomic conditions as they are described in the available literature. In 57 cases the observations were made by incision, which was frequently preceded by aspiration. In 5 cases only was aspiration alone done—Takvorian (1878), Perrier (1883), Rondot [12] (1903, case 1), Scheidler [13] (1910, case 2) and Stuparich [26] (1902). In 3 reports there was no note as to aspiration or incision.

Cases of serous inflammation of a bone following an attack of suppurative osteomyelitis in the same bone have been reported by Poncet [1] (case 3), Garré [22] and Deutschländer.[27] Donati [28] reported a case of periostitis albuminosa of a femur, which showed recovery after operation and was followed a few years later by acute osteomyelitis of the same bone. Periostitis albuminosa in one bone with suppurative osteomyelitis simultaneously in another bone of the same patient has been noted by Lipschitz [29] (1902) and Muhl [30] (1893). Rosenbach reported a case of periostitis albuminosa occurring simultaneously in a rib and a femur. Cases of periostitis or osteoperiostitis albuminosa in persons with a history of osteomyelitis have been reported by Hartwell,[4] Stropeni [16] and Moulonguet and Rousset.[17] A history of typhoid infection was

26. Stuparich: Ein Fall von Periostitis albuminosa, Wien. med. Presse **43**: 411, 1902.

27. Deutschländer: Ostitis albuminosa, München. med. Wchnschr. **8**:379, 1905.

28. Donati, cited by Stropeni.[16]

29. Lipschitz, R.: Zur Kenntnis der Periostitis albuminosa, Inaug. Dissert. (Freiburg), Berlin, M. Liebmann, 1902.

30. Muhl, A.: Ueber Ostitis und Periostitis nonpurulenta (Periostitis albuminosa, Ollier), Inaug. Dissert., Bonn, E. Heydorn, 1893.

given in the cases of Riedinger [8] (1887), Schrank [10] (1893), Rondot [12] (1903) and Hartwell.[4] Schrank (1893) stated that when these lesions are associated there is never an organic connection between them.

Formation of the Cyst and the Exudate.—The formation of cavities in the soft parts resulting from the characteristic accumulations of fluid in the older reported cases is only vaguely described. Lannelongue (1878) and Nicaise [23] (1879), who had an opportunity to examine stumps left after amputation of tuberculous joints, reported the fluid as being contained in small cavities within the thickened periosteum. Riedinger [8] (1887) denied that the cysts described were true cysts in the anatomic sense and therefore suggested the name "ganglion periostale" or "parostale" for these saclike structures. Schlange [9] (1887) described the accumulation of fluid as occurring in the following possible ways:

1. The fluid gathers under the periosteum and lifts it from the bone. In this case the bone lies uncovered in the bottom of the cyst.

2. The fluid gathers in the layers of the periosteum, breaks through their thin sheaths and develops in a cystic sac within the periosteum. In this case the bone is not exposed, but the periosteum will appear thin in the bottom of the cavity.

3. The fluid is derived *ab initio* from the outer aspect of the periosteum, or a subperiosteal or endoperiosteal accumulation of fluid breaks through early. After this, presumably because of diminished local reaction in the tissue, a diffuse, edematous swelling may form instead of a cyst. Especially likely to occur are the transudations *(Flüssigedurchtränkungen)* of the outer periosteal layers or even of the nearby structures of muscle and connective tissue described in some cases.

After the sac has once formed, its inner lining provides for its own persistence through its secretory activity, as this activity is at least as great as its resorptive powers. When there is an encapsulated exudate, the sac adheres to the bone on one side only and to a varying extent. Its walls have no definite boundaries and without macroscopic textural changes pass into the thickened periosteum. The thickness of the wall of the sac may reach several centimeters. On its exterior surface it is not sharply separated, but its fibrous tissues lose themselves in the surrounding perimysial and intermuscular connective tissues. Its inner wall is smooth and lined with a thin, veil-like layer of brownish red granulation tissue. The cavity need not be globular or ovoid but may assume complicated forms.

Lipschitz [29] (1902) also assumed the occurrence of a direct serous exudate from the abscessed membrane. In the beginning a small amount of pus is formed. This process is rapidly depressed, either because the cocci are weak in virulence or numbers and therefore impeded in their further development or because the formation of pus encounters resist-

ing tissues. From this point on, there is no further wandering out of leukocytes but rather a transudation of serum. Scheidler [13] (1910) in speaking of cysts with smooth bone exposed, without periosteal covering beneath them, stated that these cysts result from periosteal proliferation and inflammatory reaction in the surrounding tissues. If periosteal proliferation does not keep pace with the increase of fluid, the fluid breaks through into the surrounding tissue, which reacts to the irritation thus produced. Eventually the periosteum reattaches itself to the bone, and the original osseous focus heals. A similar picture is seen when the fluid escapes from a layer of the periosteum. The lesion then heals, leaving a cavity at its bottom lined with proliferated periosteum and connective tissue.

Mazzini and Brachetto-Brian [31] (1933) expressed the opinion that permanent hyperemia and an added perivascular inflammatory exudative process in the layers of the periosteum cause a transudate of plasma. This collects in the layers of the traumatized periosteum. In many reported cases since Schlange's first more detailed exposition, the sac has been described as thick—up to 3 cm. or more. The anatomic observations suggest possible formative processes as outlined by him and others, including Burckhardt [14] (1911) and Stropeni [16] (1933). Stropeni described the sac as thick, with an inner capsule lined with granulations. Moulonguet and Rousset [17] (1934) noted a thick sac the size of a kidney, the outer surface of which was smooth and regular. When it was opened it disclosed a limited cavity with a red, fungoid lining, which contained fibrinous clots and a few cubic centimeters of bloody liquid but no pus. Staph. aureus was obtained on culture.

Histologic Picture.—In the first reported histologic examination in a case of periostitis albuminosa (1878), Lannelongue observed that the periosteum covering the bone was thin but showed no change in its texture. Schlange [9] (1887) saw giant cells in the sac, and "further examination of the wall of the cyst showed a firm, cell-poor fibrous tissue, while the brown inner layer consisted of granulation tissue." Schrank [10] (1893) noted thickening of the periosteum, which involved, to some extent, both layers and which was due to hyperplasia. Near vessels were observed larger foci of round cells; the fibrillar connective tissue was distended with fluid. Battle [18] (1904) reported granulation tissue viewed microscopically and stated that there was no pus. Pickrell and Schmidt [3] (1910) expressed great doubt as to the micropathologic condition, remarking that the microscopic picture is hardly distinguishable from that of sarcoma. Sections in 2 cases "indicate fibro-chondro-osteoma." Hartwell [4] (1910) noted chronic inflammatory changes.

31. Mazzini, O. F., and Brachetto-Brian, D.: Periostitis albuminosa, Bol. y trab. de la Soc. de cir. de Buenos Aires **17**:13 (April) 1933.

Burckhardt [14] (1911) was the first to give a detailed histologic study and review of the condition up to his own time. In the case reported by him, the microscopic examination showed subacute to chronic inflammation.

> We find a poorly vascularized granulation tissue, which, so to speak, consisted only of normal and degenerated (fatty) plasma cells. Among these one sees some small foci of leukocytes but nowhere formation of abscess. Very striking, however, was the fatty degeneration and the formation of tissue, in places, from cells which conformed to those described as granular fat spheres (*Fettkörnchenkuglen*) but were devoid of fibrillar supporting substance. Aside from the fatty degeneration, we find rarely another transformation of plasma cells, namely, the formation of Russell bodies. . . . We wish to emphasize that we found these bodies only in plasma cells and that in this case there could be no thought of their origin from red blood cells. These observations conform to those described as made on pathologic granulation tissue—"sequestral granulations." The microscopic characteristics, as contrasted with those of normal granulations in wounds, are especially the large fluid content, the lack of polynuclear leukocytes and fibrin and finally the fatty degeneration of the cells.

Burckhardt reported seeing some giant cells also.

In the case described by Mazzini and Brachetto-Brian [31] (1933) the cavity was lined with pale fibrous tissue, which continued to the periosteum and its normal limits. In the bottom of the cavity the tibia, in a denuded area, was covered with a delicate layer of granulation tissue. The external layer of a portion of the periosteum removed for examination was formed of loose connective tissue, with cells, dilated vessels and moderate exudative inflammation about the vessels (polymorphonuclears and lymphocytes). The internal layer consisted of a myxomatous structure containing many small vessels and dilated capillaries. Adhering to its superficial surface was albuminous, homogeneous and amorphous matter with the appearance of colloid. In the myxomatous tissue were small areas of "osteogenesis directa." There were noted two processes, a hyaline degeneration of the connective tissue and an exudative inflammation about the vessels, occupying the distinct layers. In the vessels were seen deposits of yellow pigment. Stropeni [16] (1933) described the thickened sac as containing granulation tissue and infiltrated with plasma cells. Moulonguet and Rousset [17] (1934) stated that the wall of the sac is a pyogenic membrane infiltrated with polymorphonuclear leukocytes, i. e., an infective granuloma.

Ganglion.—Many of these cystlike formations, especially those near joints, strikingly resemble true cystlike extensions from neighboring synovial structures. Therefore, some have questioned their origin from lesions of periostitis albuminosa. Thus, Jacoby [11] (1897) expressed a suspicion that Riedinger [8] and Schreiber [32] were dealing with diver-

32. Schreiber: Ganglion periostate, München. med. Wchnschr. **40**:778 (Oct.) 1887.

ticula from a joint capsule. Plenz [33] (1929) under the title "Hygroma Migrans?" detailed a case of a cyst along the anterior aspect of the tibia which produced superficial bony spicules on that bone. He was able to follow the growth up to (but not into) a joint and decided it was a hygroma. He also expressed a strong suspicion that some cases reported in the literature as periostitis albuminosa were, in reality, instances of hygroma. His investigations showed that the contents of the sac may speak for hygroma, as well as for periostitis albuminosa. Gelatin always speaks for hygroma, even if from its location it does not appear to be associated with a bursa.

Trauma.—The incidence of trauma and the part it plays in the causation and production of periostitis or osteoperiostitis albuminosa have been variously reported and interpreted in this series of cases. Of the cases in which trauma was mentioned in the histories, it was noted as absent in 32 and present in 16. Pickrell and Schmidt [3] (1910) expressed the opinion that in the 3 cases reported by them the condition was traumatic in origin and noninfectious. They stated that the inflammation may be produced by a single severe blow over a bone or by a crushing injury to the periosteum. In the young it may be produced by a compressive force applied to the ends of a bone, springing the bone, with resulting detachment of a small area of periosteum. Likewise repeated slight injuries to an exposed bone may produce chronic periostitis. Reh [34] (1922) referred to a case reported by Heineman of noninfective post-traumatic periostitis and added that similar changes may occur after injury in old hematomas. He expressed a doubt that such a process could be classed as periostitis albuminosa Ollier. Injury, however, according to Reh, is an important factor in periostitis albuminosa. Without local damage, primary periostitis, he stated, is unthinkable except on the assumption of an anomaly of blood supply or other disturbance of nutrition through toxic or chemical influences. Mazzini and Brachetto-Brian [31] (1933) based a diagnosis of periostitis albuminosa traumatica on a history of trauma, a sterile culture and the results of microscopic examination of the sac. They pointed out that trauma produces a permanent hyperemia of the whole vascular system of the periosteum. To this is added a perivascular inflammatory exudative process, and abundant new capillary vessels are formed in the inner layers of the periosteum. The permanent local congestion causes a transudate of plasma, which by and by collects in the layers of the traumatized periosteum.

33. Plenz, P. G.: Periostitis albuminosa oder Hygroma "migrans"? Zentralbl. f. Chir. **31**:1947 (Aug.) 1929.

34. Reh, H.: Periostitis infectiosa (P. rheumatica), Deutsche Ztschr. f. Chir. **169**:168, 1922.

The Infection.—Some of the earlier writers, among them Perrier (1883), Duplay [35] (1880) and Roser [36] (1887), assumed a rheumatic diathesis as the underlying cause of periostitis albuminosa. This assumption was probably based on the resemblance of the fluid to the exudate of a joint and the previous or associated occurrence of acute or subacute rheumatic polyarthritis. Most writers, especially those whose reports have appeared since that of Schlange, have admitted the infectious character of periostitis albuminosa, which Pickrell and Schmidt [3] and Mazzini,[15] among the more recent writers, have denied. Most writers have attributed the infection to the ordinary pus organisms, namely the staphylococcus and the streptococcus, and much speculative attention is given to the seat of the primary focus of the infection.

Seat of the Lesion.—Periostitis albuminosa was first described, by Ollier and Poncet,[1] as a purely periosteal lesion. Lannelongue, who examined the condition in an amputated limb, observed no bony lesion. Ollier expressed the thought that in most of the earlier cases the disease was chronic from the beginning but stated the assumption that it may begin acutely with pain and fever. In cases of the latter description the acute symptoms subside in a short time, to be followed by a chronic course. Cartuffe [37] (1883) proposed the name "periostitis exudativa," ". . . showing that this disease is not osteomyelitis, although we do not know but that the former disease might under certain circumstances lead up to the latter." Hartwell [4] (1910) said his cases demonstrated that periostitis albuminosa is not a specific disease but the expression of irritation of the periosteum by an infecting organism of low grade virulence. Such an organism produces the characteristic albuminous exudate rather than pus. He added that it is not known why this is so.

Schlange [9] (1887) expressed the opinion that in these cases the germ of osteomyelitis may be present in smaller amounts or in an attenuated phase or attack a person less predisposed. In short, conditions are unfavorable for the production of a more intense inflammation and the disease, therefore, is subacute from the beginning. On the other hand, the inflammation may be more active in the beginning but, because of early encapsulation, be hindered in its full activity. This view suggests only a difference of degree between the purulent and the nonpurulent form of osteomyelitis. Jaksch [38] (1890), Schrank [10] (1893),

35. Duplay, M.: Périoste externe rhumatismale (périostite albumineuse d'Ollier), Arch. gén. de méd. **146**:728, 1880.

36. Roser, W.: Zur Lehre von der Periostitis albuminosa, Zentralbl. f. Chir. **14**:929 (Dec.) 1887.

37. Cartuffe, cited by Dupuis.[2]

38. Jaksch, R.: Zur Lehre von der Periostitis albuminosa, Wien. med. Wchnschr. **49**:2097 (Dec.) 1890.

Ehrich [39] (1896), Lexer [19] (1898), Lipschitz [29] (1902), Deutschländer [27] (1905), Reh [34] (1922), Stropeni [16] (1933) and Moulonguet and Rousset [17] (1934) all expressed more or less agreement with Schlange. They stated the assumption that the primary lesion originates in the periosteum, below the periosteum, in the cortex or in the medullar cavity. The primary seat of the infection is obviously difficult to determine, as exposure of bone or a cortical lesion does not prove that the bone was primarily affected. Likewise, an apparently intact periosteal covering does not necessarily speak for a nonosseous origin of the lesion. A study of the color plate suggests the presence of various possible primary foci in the available recorded cases. Moulonguet and Rousset [17] (1934) described their cases as an attenuated form of osteomyelitis and suggested the term "forme fruste." They quoted Lecine and Leriche as declaring the condition to be cortical osteitis, very superficial and highly localized.

Tuberculosis.—Roser [36] (1887) expressed a suspicion that in some of the earlier cases described as instances of periostitis albuminosa the condition was really tuberculous, as in those of Nicaise [28] and Lannelongue. He stated the belief, however, that cases of tuberculous periostitis occur in which the exudate is watery or watery-purulent. Legiehn [40] (1890) expressed the opinion that in 2 of the 15 cases reported up to his time the condition was tuberculous. The cases of Breuer [24] (1893) and Sleeswijk [25] (1894) were obvious cases of generalized tuberculosis. Rondot [12] (1903) reported the condition in his third case as periostitis albuminosa in a hip which had previously been the seat of tuberculosis. Riedel made the following annotation at the end of Sleeswijk's thesis: [25]

> It is well known that osteal or periosteal tuberculosis may cause a serous exudate—it is very probable that many earlier cases described as periostitis albuminosa may have been tuberculosis. In general it will be held that "osteitis and periostitis albuminosa" are the result of an attenuated staphylococcic, streptococcic or other infection. If one were to include tuberculosis as an etiologic factor, one would call the condition "osteitis or periostitis albuminosa tuberculosa."

Most writers, especially the more recent ones, have stressed the importance of considering tuberculosis in the diagnosis of these conditions. Moulonguet and Rousset [17] (1934) warned that "cold abscesses are not all tuberculous." In 1 of their cases, the nontuberculous character of the disease was established after the patient had been for years under treatment (mistakenly) for a tuberculous disease of the hip. Roser [36]

39. Ehrich, E.: Ueber latente Eiterherde im Knochen, München. med. Wchnschr. **43**:693 (July) 1896.

40. Legiehn, F.: Ueber die sogenannte Periostitis und Ostitis albuminosa (Ollier), nebst Mittheilung zweier Krankengeschichten, Inaug. Dissert., Königsberg, M. Liedtke, 1890.

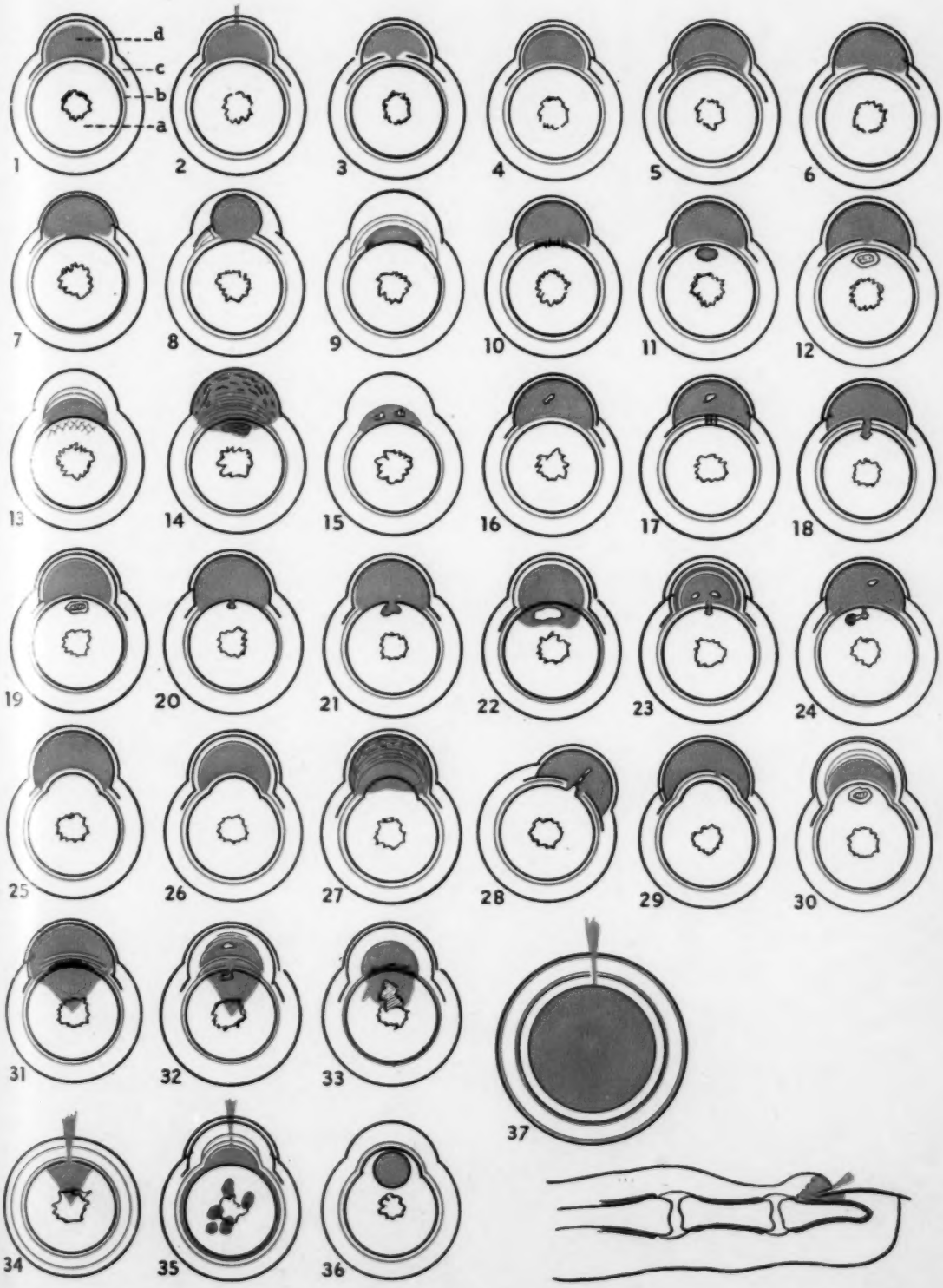
Explanation of Color Plate

a represents a cross section of a long bone (black); a bulge in this outline (as in *25*) represents cortical thickening of the bone; roughening of the cortical surface and formation of cavities with and without sequestrums are indicated by special markings; in *37* the diagrammatic representation is relatively larger to convey the idea of an enlarged bone with cortical thinning and a central cyst. *b* represents periosteum (red). *c* represents the soft parts surrounding bone. *d* represents the cystic accumulation (green) in the soft parts or within the bone.

The numbers under diagrammatic figures *1* to *37* represent the various types of lesions as described in the literature as follows:

1. Bar, Rondot (case 6), Scheidler (case 1), Hartwell (case 3). *2.* Duplay. *3.* Moulonguet and Rousset (case 1). *4.* Lannelongue (cases 1 and 2), Rosenbach, Perrier. *5.* Rondot (case 4), Roser. *6.* Mazzini, Cazin. *7.* Jacoby, Legiehn (case 1). *8.* Hartwell (case 2). *9.* Riedinger, Nicaise, Stropeni, Schreiber, Poncet (case 3). *10.* Poncet (case 2). *11.* Lipschitz. *12.* Moulonguet and Rousset (case 2). *13.* Hartwell (case 3), Lecine and Leriche. *14.* Schlange (case 2), Scheidler (case 2). *15.* Jaksch. *16.* Kuth (case 2). *17.* Mennen. *18.* Muhl. *19.* Czerny. *20.* Schrank (case 1). *21.* Ollier. *22.* Savariaud. *23.* Schlange (case 1). *24.* Schrank (case 2). *25.* Albert. *26.* Terrier. *27.* Dupuis. *28.* Hartwell (case 1), Pickrell and Schmidt (cases 1 and 2). *29.* Reviglio. *30.* Riedel. *31.* Burckhardt, Battle. *32.* Schlange (case 3). *33.* Legiehn (case 2), Beekenkamp. *34.* Lexer. *35.* Deutschländer, Garré. *36.* Schlange (cyst). *37.* Ehrich (cyst).

The diagrammatic sketch in the lower right corner represents the finger in case 4, showing the site of the lesion and the sinus (green).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(1887) took issue with Riedinger and Schlange, maintaining that the condition (periostitis albuminosa) as described is not a clinical entity. Schrank [10] (1893) expressed the thought that in the reported cases it did not present a uniform, sharply defined clinical picture. If the cases were to be regarded as instances of a single disease, he stated, the limits of the definition would have to be widened considerably. Sleeswijk [25] (1894) pointed also to the difference in opinion regarding the seat of the disease, the nature of the exudate and its causation.

Origin and Character of the Exudate.—Since Poncet's first publication, much interest has been shown and much speculation indulged in relative to the origin of the peculiar exudate. Ollier stated the assumption that the fluid arises from either the bone or the periosteum. Duplay [35] (1880) expressed the opinion that the serous exudate is the first stage of every inflammation; in this case the inflammation remains in that stage, not going on to suppuration. This exudate may originate outside and independent of the periosteum, and is due to a rheumatic diathesis. Riedinger [8] (1887) stated the thought that under certain conditions the periosteum can put forth a product as tendon sheaths put forth ganglions. He saw the same chemical characteristics in the fluid of the ganglions produced by the tendon sheaths as in the accumulated fluids of periostitis albuminosa. He expressed the opinion that periostitis does not represent an inflammation in the ordinary sense of the term. It consists rather of a perspiring (*Ausschwitzung*) of fluid from the involved soft tissues.

Schlange [9] (1887) stated his assumption that the fluid originates from an osseous lesion. He expressed the opinion that periostitis albuminosa is not the result of chronic and persistent osteomyelitis in the sense that the peculiar fluid is a modification of an osteomyelitic abscess. That is, it is not the product of a gradual change of pus into serum. Against this is the observation of serous fluid early in the course of the disorder and the lack of foundation in pathology for such a supposition. He stated the belief that the characteristic exudate is due to the organisms of suppurative osteomyelitis, which are present in small numbers in a phase of diminished virulence. For these reasons, he said, or because of the lessened susceptibility of the person attacked, they do not form ordinary pus.

Vallert [41] (1890) stated that the exudates are due to abscesses which have originally a purulent content but gradually undergo a mucoid metamorphosis. Breuer [24] (1893) expressed his feeling that the occurrence

41. Vallert, J.: Ueber die sogenannte Periostitis albuminosa nach Erfahrungen aus der chirurgischen Klinik zu Halle, Samml. klin. Vortr., no. 351, 1890 (Chir. no. 108, pp. 3355-3372); cited by Kaufmann, E.: Lehrbuch der speziellen pathologischen Anatomie, ed. 6, Berlin, Georg Reimer, 1911, vol. 2, p. 689.

of fat, calcium and phosphates speaks for an osseous origin of the fluid. The exudate can, however, develop independently from the walls of the cyst. Lipschitz [29] (1902) said that the fluid is derived as a direct serous exudate from the membrane of the abscess. In the beginning a small amount of pus is formed, a process which is rapidly depressed, with no further wandering out of leukocytes but with more transudation of serum. Whether the mucoid character of the exudate is due to degeneration of elements in the wall of the abscess or, as Vallert would have it, to a mucoid metamorphosis of the original pus is undecided. Garré,[22] in support of Vallert's theory, offered his observation of a case in which the first aspiration showed pus and eight weeks later, on incision, mucoid exudate was found. He stated the belief that pus can be so thinned by a transudate of serum or lymph as to give rise to a rapid increase in the swellings. In a case reported by Jacoby [11] (1897) in which a culture of Staph. aureus was obtained the typical serous exudate became purulent a few days after incision for drainage. Muhl [30] (1893), Ehrich [39] (1896), Lexer [19] (1898) and Hartwell [4] (1910) offered no explanation of the formation of the exudate. Schrank [10] (1893) supported Schlange and expressed the thought that the exudate arises from a degenerative process of the granulations rather than from a fatty or mucoid degeneration of the pus.

Burckhardt [14] (1911), confirming the microscopic observations of Schlange and others, stated that the phenomena which they observed conform to those described by Reinbach [42] as pathologic granulation tissue *(Sequestergranulationen)*. Reinbach pointed out a form of inflammation on the surface of the body in which the amount of serous exudate is many times that of granulation in healthy wounds. In the exudate of such inflammations, he said, the newly formed cells "swim." The cause of this process lies in the fact that the inflammatory stimulus is not strong enough to call forth a sufficient proliferation of tissue. The leukocytes, therefore, cannot be lured on (*angelockt werden*) by the stimulating agent of the inflammation. The formation of the exudate may be explained by an abnormal permeability of the walls of the vessel or, per contra, by an activity of their cells. The first explanation can, according to Burckhardt, be drawn to the support of his case in view of the fatty degeneration of the endothelial structures. Kocher and Tavel [43] said that the serous exudate results from fatty degeneration of granulation tissue. Aschoff [44] stated his feeling that periostitis albuminosa follows periostitis purulenta, in which granulation tissue secretes

42. Reinbach: Untersuchungen über den Bau verschiedener Arten von menschlichen Wundgranulationen, Beitr. z. path. Anat. u. z. allg. Path. **30**:102, 1901.

43. Kocher and Tavel, cited by Kaufmann, E.: Lehrbuch der speziellen pathologischen Anatomie, ed. 6, Berlin, Georg Reimer, 1911, vol. 2, p. 689.

44. Aschoff, cited by Reh.[34]

serous fluid. Reh [34] (1922) expressed his inclination to Vallert's view; he stated the belief that no primary periostitis albuminosa, as such, exists. Stropeni [16] (1933) expressed his acceptance of Vallert's view as to the origin of the fluid. Mazzini and Brachetto-Brian [31] (1933), as noted in the section entitled "Trauma," attributed the formation of fluid to permanent hyperemia of the vascular system of the periosteum and to perivascular inflammation.

Breuer [24] (1893) and Sleeswijk [25] (1894) drew attention to the change of the fluid in tuberculous abscesses from a purulent to a mucoid form after repeated injections of iodoform and glycerin. Thereby they suggested the possibility of similar changes in the exudates here in question. Scheidler [13] (1910) quoted Henle, who stated the belief that pus will be transformed to a serous exudate only as a result of treatment, such as repeated aspirations or injections. Scheidler further stated that there exist no reported observations of a case in which serous abscesses were associated with tuberculosis. The origin of the fat seen in many of the exudates was attributed by Ollier [7] (1874), Schlange [9] (1887), Roser [36] (1887), Muhl [30] (1893) and others to the bone (marrow). Schrank [10] (1893), Burckhardt [14] (1911), Kocher and Tavel,[43] on the other hand, attributed it to fatty degeneration of the granulation tissue. The question, therefore, has been: Is the exudate serous from the beginning, or is it changed pus? Can the usual pus organisms under certain conditions produce a serous exudate or not?

Roentgenographic Examination.—Rondot [12] (1903) was the first to record the use of roentgen rays in the diagnosis of this condition. The roentgenogram, however, was too poor to be of use. Battle [18] (1904), with the aid of roentgen rays, was able to determine an infectious periosteal thickening and differentiate it from malignant osseous tumor. Deutschländer [27] (1905) in a case of osteomyelitis albuminosa following open fracture of a bone observed typical osteomyelitic foci roentgenologically in the medullar cavity. Scheidler [13] (1910) pointed out that the roentgen examination may reveal the type of lesion and indicate what extent of surgical intervention is desirable. He indicated that because of excessive fluid or great thickening of the wall of the cyst the roentgenogram may appear poor. The plates show the extent of the fluid in the soft parts, but for better bony detail it should be aspirated and the roentgen examination repeated. In 1 of his reported cases the roentgenogram showed thickening of the cortex over the inner and outer aspects of the bone and extensive shadow of the soft part. A depression in the upper third of the femur was seen only after evacuation of the fluid, but there was no lesion in the medullar cavity. In a second case, there was noted a localized bony focus near the upper epiphysis of the humerus, leading to an area of destruction in the head of the bone as

well as to a lesion near the epiphysis of the acromion. Here again he pointed out the distinct difference in the roentgenograms taken before and after aspiration. Pickrell and Schmidt [3] (1910) in 3 reported cases noted on roentgen examination a marked bony proliferation, in 1 case "resembling myositis ossificans" and in another presenting a fusiform shadow.

In Hartwell's case [4] (1910) the roentgenograms suggested tumor. Burckhardt [14] (1911) observed in the distal end of a femur, reaching to the middle of the bone, a superficial proliferation 2 to 3 mm. in thickness, casting a definite shadow. The compact part of the distal end of the bone was noticeably smaller and showed toward the medullar cavity an irregular contour. The medullar cavity presented a turbid shadow, which in places was not sharply separated from the compact bone. Mazzini [15] (1932) reported negative results from roentgen examinations. Stropeni [16] (1933) in a case of involvement of the skull reported the roentgenogram as showing perfect integrity of the frontal bone. He quoted Revigilio, who in roentgenologic studies found areas of rarefaction in trabeculae, due to demineralization, which produced in the roentgenogram an almost homogeneous appearance of the bone. The trabeculae were smaller than those of normal bone, and periosteal hyperactivity with irregular calcification was noted. Revigilio stated also that if macroscopic examination of the bone shows periosteal involvement, the lesion, even though not evident, is nevertheless primary in the bone as attenuated osteomyelitis without destruction. Moulonguet and Rousset [17] (1934) in roentgenograms taken in 1 case saw an osteophyte on the ilium between the anterior inferior spine and the acetabulum. There was no bony atrophy, and the hip joint was apparently normal; in a second case they noted lamillary osteitis of the ilium above the acetabulum. They stated that in general roentgen examination in cases of periostitis albuminosa will show absence of decalcification and production of new bone.

REPORT OF CASES

The following cases are the personal observations to which reference was made in the introductory paragraph of this paper:

CASE 1.—Mrs. L. S., aged 36, was seen in November 1931, complaining of pain and soreness in the right calf, which she stated began about one year previously. The soreness was accompanied by a slight swelling of the right calf and caused intermittent lameness. About two months before, a swelling began in the back of the right knee (popliteal space), which was not painful or tender to touch or pressure but was gradually increasing. The familial and the personal history revealed nothing of interest. There was no history of injury, but the patient admitted falling frequently because of "weak ankles." There was no history of infection, except that some years previously she had had what she thought was inflammatory rheumatism in the right knee and left ankle.

Examination showed a well developed, well nourished woman with the appearance of good health and no abnormalities other than the swelling and lameness. The temperature was normal, the pulse rate 84 and the blood pressure 122 systolic and 78 diastolic. The Wassermann reaction was reported negative. The right calf was slightly larger than, but otherwise no different from, the left. In the right popliteal space was noted a swelling about the size of a goose egg, firm but showing some resiliency on pressure, like a tightly filled cyst. The skin and soft tissues over this swelling appeared normal but possibly slightly warmer than the surrounding tissues. Neurologic examination of the lower extremities showed no abnormality. A roentgenogram of the knee, made in two positions, showed only the shadows of the soft parts, with a small, irregular denser shadow in its outer limits in the lateral view (fig. 1).

Fig. 1.—Roentgenogram made in case 1 (Mrs. L. S.). The arrow points to the sequestrum.

It was assumed that the patient had a cyst or ganglion arising from synovial structures in or about the knee joint or possibly a malignant tumor. Therefore, on November 19, the affected part was explored surgically by a longitudinal mid-popliteal incision. Under the superficial fat, a slightly oval tumor, measuring about 3½ by 4 inches (9 by 10 cm.), was exposed. It was moderately adherent to the surrounding soft structures and was grayish white over its external surface, with definite fluctuation. After it was freed by sharp and blunt dissection, the external popliteal nerve was seen to pass over the tumor and the large vessels to pass along its inner side. The capsule of the tumor was observed attached by dense scar tissue to the surrounding soft parts at its inner and distal surface and to the femur at its proximal end. While being removed, the tumor (cyst) broke, evacuating a large amount of clear brownish fluid, thick, sticky and resembling

synovia. With the fluid, escaped a small, irregularly shaped piece of necrotic bone (sequestrum). The cyst was completely removed. No evidence of disease was seen in the exposed portion of the femur, where the sac had been intimately connected with the bone by denser scar tissue.

Results of pathologic examination were reported by Dr. George Berdez, of St. Mary's Hospital: "Macroscopically the specimen is a sac-shaped structure, measuring 8 by 6.4 cm. The wall of the sac measures from 0.5 to 1.2 cm. in thickness and is formed of masses of scarlike fibrous tissue. Its internal surface is extremely congested and shows diffuse hemorrhages. At one of its extremities, its external surface shows a piece of striated muscle, which is involved in the mass of scarlike connective tissue. The sac still contains a small amount of hemorrhagic, purulent material and a hard specimen of irregular shape, measuring 1 by 1 by 0.3 cm., apparently formed by bony tissue. Microscopically the wall of the sac is seen to be formed of rather tough connective tissue. Its internal surface is lined with cellular granulation tissue, which is densely infiltrated with lymphocytic, plasmatic and polymorphonuclear cells. In places there are diffuse hemorrhages and deposits of hemosiderin. No tubercules are observed. Sections through the smaller piece of bone show that it is formed of irregular, thin, anastomosing bony trabeculae; the medullar spaces are filled with necrotic fibrous and adipose tissue."

No bacterial examination was made. The wound healed by primary union, and the patient reported herself fully recovered in July 1936.

This case is similar in practically all respects to a number of the recorded cases, resembling, especially in the location of the process, the cases of Revigilio,[45] Savariaud and Mennen.[46] The location, in the popliteal space, suggests the possibility of hygromatous extension from the knee joint or the neighboring tendons or bursas. The entire independence of the process from the knee joint and bursal structures was demonstrated. The initial lesion was either a primary periostitis or primary cortical osteitis with separation of a small, flat sequestrum, followed by healing. Scar tissue was formed in the bone cortex and the periosteum and the fluid and sequestrum encapsuled. The symptoms appeared gradually and persisted for ten months before swelling was noticeable in the popliteal space. This suggests that most of the exudate accumulated during the latter two months, after the osseous or periosteal lesion healed and the sac separated from the original focus of infection (color plate, *17*). The excess exudate would most likely be derived from the inner lining of the sac as a "secretion," as has been suggested by Schlange[9] and others. (Schlange's view is discussed in the section entitled "Formation of the Cyst and the Exudate.") It is probable likewise that the thickness of the sac and the tendon within it increased more rapidly during the latter two months. Whether the exudate was serous or purulent from the beginning cannot be determined in this case. Trauma does not appear to have been a factor. The infectiousness of the

45. Revigilio, cited by Stropeni.[16]

46. Mennen, W.: Zur kenntnis der Ostitis albuminosa, Inaug. Dissert., Jena, G. Neuenhahn, 1892.

disorder is evident from the histologic examination of the sac and the character of the sequestrum. The history of "inflammatory rheumatism" in the right knee and left ankle suggests a previous infection, which possibly caused the lesion in the distal end (metaphysis) of the femoral shaft. Had this subacute type of lesion in the cortical bone been in mind, the significance of the small shadow noted roentgenographically in the soft parts might have been appreciated. In that case it is possible that the correct diagnosis could have been made preoperatively.

The case of Mennen [46] (1892) holds a considerable degree of interest in connection with case 1 here reported:

A woman aged 21 complained of gradual onset of mild pain during one and one-half years, with swelling in the right popliteal space of about the same duration. Two aspirations preceded the incision, one fourteen or fifteen months after the onset and a second three or four months later. At the first aspiration there was a clear light fluid and at the second nearly a liter of yellow, transparent albuminous fluid. The latter was not stringy and contained small white particles which were seen microscopically to consist of fibrin with numerous white blood cells. Two weeks after the second aspiration, at the time of operation, the cyst had again filled to its original size with a clear yellow serum. At operation it was found to be impossible to remove the sac, because of surrounding dense adhesions, and treatment therefore was limited to simple incision and drainage. The walls of the sac measured from 1 to 1.5 cm. in thickness and were dense, with areas of localized thickening. Lying free in the sac, near the lateral condyle, was a sequestrum the size of a pea. No defect was noted in the bone, which was covered completely by periosteum (color plate, *17*). The periosteum and also the whole inner wall of the sac were covered with soggy granulations of satin-like texture. In this case, from the behavior of the exudate after each evacuation, it is evident that it was derived from the wall of the sac.

Case 2.—L. L., a waitress, aged 19 and single, consulted Dr. W. C. Martin for disability of the left elbow and forearm following an accidental injury on Nov. 30, 1935. She stated that she struck the back of her left elbow against a bannister and that six days later a small swelling appeared over the front of the left forearm. The swelling was seen just distal to the bend of the elbow. She complained of soreness over the back of the left elbow at the distal end of the upper part of the arm and over the inner condyle of the humerus. There was also moderate soreness in a small swollen area on the flexor surface of the left forearm an inch or so distal to the elbow. I saw the patient on December 27, at which time examination showed the swelling in the site described, the size of a large pecan. It was moderately firm, apparently movable and not attached to the muscles or tendons. The skin over the swelling was normal. Movements of the left upper extremity also were normal. Further examination showed the blood and the urine normal and the Wassermann reaction negative. The reaction to the Mantoux test was 1 plus. Roentgen examination on December 6 showed moderate swelling of the soft parts and a small, irregular shadow lying in the soft tissues anterior to the neck of the radius. The bone showed no obvious abnormalities (fig. 2).

The patient was next seen on Jan. 24, 1936, at which time the swelling of the forearm was about the size of an orange and showed definite fluctuation. A roentgenogram, which had been made on January 21, showed the small shadow previously noted occupying a position higher and farther from the bone (fig. 3).

Fig. 2.—Roentgenogram made in case 2 (L. L.) on Dec. 6, 1935. The arrow points to the sequestrum.

Fig. 3.—Roentgenogram made in case 2 on Jan. 21, 1936.

The patient had been able to continue her work up to this time but complained as before. At no time were there any constitutional symptoms of infection. The familial and the personal history revealed nothing of interest except a suppurative condition in the upper part of the right femur during the patient's early childhood. This condition left her with deformity and shortening of the right leg. The general examination showed no other abnormality.

In view of the similarity of this case to case 1, a diagnosis of mild, subacute infectious osteoperiostitis was made, and on January 26 the swelling was incised and drained. Abundant clear, thick, sticky yellow fluid with large and small fat globules floating on its surface, clots of fibrinous exudate and a small sequestrum were evacuated. The head and neck of the radius, palpable in the depths of the empty cavity, felt normal. No more satisfactory inspection was possible. The fibrinous clots had a striking lemon yellow tint. No definite sac was formed; the fluid appeared immediately below the deep fascia, apparently displacing the soft structures. A simple cigaret drain was inserted.

A pathologic examination was reported by Dr. George Berdez, of St. Mary's Hospital, as follows: "Macroscopically the specimen is a piece of bone, irregular in shape, measuring 1.4 by 0.5 by 0.15 cm., showing jagged edges and a rough surface. Microscopically it is seen to be formed of rather compact bony tissue, in which osteoblasts no longer stain. The edges of the bone are rough and irregular, showing signs of resorption. The tissue in the haversian canals is necrotic. A small amount of cellular connective tissue is still attached at one place to the surface of the specimen. Smears from the material show numerous polymorphonuclear cells and a few gram-positive diplococci."

Culture made from the fluid showed a pure strain of Staph. albus. The subsequent recovery was uneventful. The patient was apparently well in November 1936.

Clinically this case resembled case 1 in the subacute course, the accumulation of characteristic exudate, the sequestration of cortical bone and especially the roentgenographic appearance. The disease was definitely attributed to trauma, although the trauma was not to the part where the lesion occurred. The case differs from case 1 in the prompter appearance and the more rapid increase of the swelling. The fluid also, unlike that in case 1, was free in the subcutaneous tissues, contained in a large cavity without a definitely limiting wall. The condition of the bone was determined by palpation only, and the observations, therefore, are not conclusive. As in case 1, the lesion was either a primary periostitis or cortical osteitis with separation of a sequestrum, which was extruded into the exudate. The site of sequestration in the weeks prior to incision may have been covered sufficiently with granulations or scar tissue to elude the palpating finger (color plate, *16*). Another striking feature of this case was the observation of free-floating fat globules on the exudate and lemon yellow clots of fibrin, obviously representing fatty degeneration. The latter observation points to the clots, rather than to the bone, as the source of the fat in the exudate. The comparatively rapid accumulation of fluid suggests a primary serous exudate, but here also the character of the initial exudate must be left

to conjecture. The cause of this infectious bony lesion may have been the suppurative disease in the upper end of the right femur in early childhood.

CASE 3.—E. P., a woman aged 41, a teacher, was first seen on Sept. 10, 1936. She had a red, ridgelike swelling of the soft parts over the root of the nail in the left middle finger. The symptoms had begun about July 4, following a severe contusion of the end of the finger. From time to time, as the swelling became tense, there would occur a discharge of a clear, jelly-like fluid from the space between the nail and the covering soft parts. After the discharge the pain and soreness would disappear, only to recur as the same peculiar jelly-like fluid again collected. Ordinary local treatment did no good. On October 10 the patient received a therapeutic dose of roentgen radiation over the finger, and one week later the symptoms had nearly disappeared. Several similar treatments were given, but when the patient was next seen, on Jan. 9, 1937, the condition was as first seen, in the preceding September. The discharge of jelly-like fluid recurred as before, the pocket filling and emptying at weekly intervals. At this time a roughened groove was noted, extending longitudinally down the middle of the nail from the point where the exudate escaped. It was about 1/16 inch (0.16 cm.) in width. Roentgen examination of the finger on January 9 showed no obvious abnormalities of the bony structures of the involved phalanx.

On January 16, the swelling was incised and the soft parts lifted from the nail. Practically the whole root of the nail and the insertion of the tendon of the extensor muscle were thus exposed. The swelling at the time was, as usual, about the size of a pea and was tense, with redness of the soft parts. When the swelling was incised, a drop of the characteristic white jelly escaped. The root of the nail was seen to be loosened from its bed, and this portion of the nail was removed. A small, narrow, ridgelike area, just distal to the attachment of the tendon of the extensor muscle, was observed, covered with firm granulations. When these were removed, a small, narrow line of bare bone was noted. The wound was left open and filled with petrolatum. The jelly-like exudate yielded a pure culture of Staph. albus. On January 22, 2 cc. of a suspension made from the growth on gelatin was injected into the vein of the ear of a 15 week old rabbit. This experiment will be discussed later.

CASE 4.—J. H., a man aged 42, an accountant, had sustained an injury to the end of the ring finger eighteen years previously. Subsequently the finger was somewhat sore but caused only slight annoyance. Six years before the time of this record, another injury to the end of the same finger caused it to become swollen, and since then the swelling had been variable. When the swelling reached its height, the patient by squeezing evacuated a light fluid, which he stated had been "crystal clear" since the beginning of the trouble six years before. He stated that the swelling generally reached its maximum in about two weeks and that the finger was not especially sore or tender until then. After evacuation of the fluid, the discomfort in the finger eased. On Sept. 20, 1936, the swelling was incised and curetted and the wound sutured. The attacks, however, recurred within ten days after this procedure. After that time the swelling had been punctured several times. A roentgenogram of the finger made on August 26 showed no obvious abnormalities of the bony structures.

When I saw the patient, on November 5, the end of the right ring finger presented a firm red swelling in the soft parts above the nail. At its dome was a small grayish white area of hard and horny epithelium, coinciding with the

location of the sinus, which was closed at that time. The nail appeared roughened, showing marked trophic disturbance. A small V-shaped portion of the root of the nail was exposed, because of scarring and contraction following the previous incisions. Besides these abnormalities, the distal joint of the fourth finger, as well as the distal joint of the index and little fingers, of the right hand showed Heberden's nodes. Otherwise the fingers were normal in function and appearance.

Three therapeutic exposures of roentgen rays were given without apparent effect on the process. On December 11, the whole indurated swollen area was excised, and the undermined, loose part of the nail was removed. The defect in the finger was filled with petrolatum and a simple dressing applied. After removal of the indurated tissues and the sinus, the latter was found to extend to a small exposed area of bone on the dorsum of the distal phalanx. Just distal to this, the root of the nail was loosened from its bed (fig. 4 and diagram in lower right corner of color plate). Culture made from the exposed bone resulted in a growth of streptococci.

Results of a pathologic examination were reported by Dr. George Berdez: "The specimen from the top of the swelling measures 1.1 by 0.6 by 0.3 cm. The upper surface is covered with a thin skin and shows a small irregular opening of a sinus. The deeper layers of the specimen are formed of a rather compact, scarlike fibrous tissue. A smaller specimen, received separately, measures 0.3 by 0.2 by

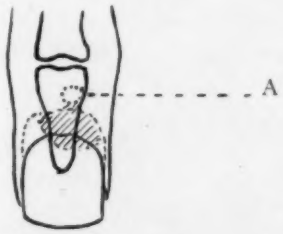

Fig. 4.—Diagram of the finger in case 4, showing the area of denuded bone at *A*.

0.2 cm. and is formed of red tissue of irregular shape. A third specimen is formed of a mass of fibrous tissue and measures 0.7 by 0.3 by 0.2 cm. There is also a piece of nail measuring 0.7 by 0.5 cm. and about 0.7 cm. in thickness. Microscopically the skin shows a horny layer of irregular thickness with signs of marked desquamation in places. This stratified squamous epithelial lining of the skin is fairly regular. The corium is rather fibrous and shows several small perivascular foci of cellular infiltration, with lymphocytic cells mainly. A few sweat glands, which are included in the section examined, show a slight dilatation of their lumens. The smaller specimen received separately is formed by a mass of rather fibrous connective tissue, which is infiltrated with a few scattered lymphatic cells."

On Jan. 18, 1937, the initial dressing was removed and the wound noted to be completely healed.

These 2 cases resemble closely a case reported by Edington [47] (1899), that of a woman aged 79 with an indolent swelling of three months' duration about the matrix of a finger nail. Incision produced a clear

47. Edington, G. H.: Periostitis albuminosa, Brit. M. J. **2**:1099 (Oct. 21) 1899.

gelatinous material "precisely like that of simple ganglion." Examination of the fluid showed the presence of mucin. Microscopic examination showed degenerative flattened cells and here and there cocci arranged in chains. Edington referred to the absence of bursas in these localities and in conclusion expressed the thought that this case must be added to the bibliography of periostitis albuminosa. No other cases similar to that of Edington and the 2 here reported have been found in the literature. In case 4, the bone was bare and the root of the nail undermined, but the nail bed was intact. In case 3, a similar condition was noted, except that the small linear area of roughness was seen only after removing firm granulations. In these cases (3 and 4) there can be no thought of a previous purulent exudate changed into a gelatinous one, as the exudate reformed immediately after its evacuation. In case 3 there were noted in some of the terminal joints slight hypertrophic changes; Heberden's nodes and sharpening of the margins of the joints were seen in the roentgenogram. In case 4 these changes were somewhat more pronounced. Whether the changes or the nearness of the lesions to a tendon, if not to a joint, played a part in determining the character of the exudate is left unanswered. Careful inspection at the time of incision showed no obvious direct connection with any structures except exposed bone.

EXPERIMENT IN ANIMAL INOCULATION

A 15 week old rabbit was inoculated through the vein of an ear with 2 cc. of emulsion from a three day growth on gelatin of staphylococci obtained in case 3. The animal remained well and was killed after fifteen days. Examination showed no gross visceral lesions suggesting pyogenic infection. Both femurs with their periosteum were removed and showed no gross evidence of infection. One femur was placed in an incubator and left for thirty-six hours. The other femur was split longitudinally and the distal halves prepared in paraffin sections and stained by the Gram-Weigert method and by the use of hematoxylin and methylthionine chloride (methylene blue) and eosin. The first femur after thirty-six hours was treated similarly. Careful examination showed no cocci or demonstrable foci of infection in any part of the various specimens. Search was directed especially to the areas of the arteriovenous capillaries at the metaphyseal side of the epiphyseal cartilage.

Lexer,[48] Hobo[49] and Robertson,[50] among others, have shown that staphylococci injected intravenously into young animals produce foci of

48. Lexer, E.: (*a*) Die Entstehung entzündlicher Knochenherde und ihre Beziehung zu den Arterienverzweigungen der Knochen, Arch. f. klin. Chir. **71**:1, 1903; (*b*) General Surgery, New York, D. Appleton and Company, 1910, p. 236.

49. Hobo, T.: Zur Pathogenese der akuten haematogenen Osteomyelitis, Acta scholae med. univ. imp. in Kioto **4**:1, 1921.

50. Robertson, D. E.: Acute Haematogenous Osteomyelitis, J. Bone & Joint Surg. **9**:8 (Jan.) 1927.

infection in the spongy end of the diaphysis of a long bone, near the epiphysis. According to Lexer,[48b]

> If old attenuated cultures of the yellow or white staphylococcus are injected the animal remains sick for a short time, but recovers. During the course of the sickness several hot painful swellings develop upon one or more legs, and as the swelling of the soft tissues subsides, the thickening of the bones, which after two or three weeks present all the pathological changes of chronic suppurative osteomyelitis, as it occurs in man, becomes more distinct.

The negative result of animal inoculation in case 3 corresponds to the negative results obtained by Garré [22] (1891), Scheidler [13] (1910) and Mazzini [15] (1932) and denotes an organism of low virulence. The results obtained by Dor [21] (1895) and Stropeni [16] (1933) from animal inoculation likewise point to an attenuated organism.

COMMENT

A review of the foregoing material shows that the lesions in the recorded cases were chiefly (93 per cent in this series) periosteal or cortical in origin. In their tendency to involve the superficial bony structures, in their clinical course and in their charcateristic exudate, they differ from those of ordinary osseous infection. Only in their subacute course do they resemble the rarer forms of attenuated infection associated with the names of Brodie and Garré. For this reason, I do not hesitate, in the subtitle of this paper, to associate the name of Ollier with this form of chronic bony infection. The cases of Legiehn (Mikulicz) (1889), Beekenkamp (1890), Lexer [19] (1898), Deutschländer [27] (1905) and Garré [22] (color plate, *33, 34* and *35*) represent lesions which were probably cortical from the beginning (osteomyelitis). The case of Deutschländer was one of direct primary infection of the marrow cavity following an open fracture of a bone. In the remaining cases of this group the infection spread locally from a primary focus in the spongy part of the broadened metaphysis (subepiphysial) of bone secondary to generalized bacteremia. This process is described by Lexer,[48] Hobo [49] and Robertson.[50] Of special interest are the cases of osteomyelitis albuminosa reported by Ehrich [39] and by Schlange,[9] the latter described in connection with 3 others, which Schlange designated as instances of "nonsuppurative osteomyelitis" of the femur. Schlange stated a preference for the term nonsuppurative rather than albuminosa. A careful study of his cases (color plate, *14, 23* and *32*) suggests that they involved a primary cortical and not an osteomyelitic lesion.

> In Ehrich's case (color plate, *37*) a cyst of the distal end of the tibia occurred in a man aged 23, after an acute onset, with high fever, pain, redness and swelling. There was a tumor-like swelling of the bone, which on incision yielded a stringy, synovia-like fluid. The cavity was lined with thick, firm granulations, and under

these was a smooth bony wall. Bacterial examination showed on culture pyogenic staphylococci. The patient recovered.

In Schlange's case of a boy aged 14, there had occurred a contusion of the tibia one and one-half years previously, followed by tenderness and swelling with fever and malaise. This was followed by a gradual recovery, but some fusiform swelling of the upper third of the tibia remained. At the time of surgical exploration, the cortex was thin and parchment-like and the cavity ovoid, filled with brown serous fluid and lined with soft dark brown tissue. The underlying bone was soft and porous. The fluid contained a few red and white blood cells and occasional fat cells and was albuminous. In the fluid were a few clumps of brown-red tissue, which was poor in cells and contained giant cells. The osseous specimens were lost, and no further microscopic or bacteriologic examination was made. Recovery was uneventful.

A considerable degree of speculation continues as to the causation of many so-called simple bony cysts which have been reported, such as those described by Schlange. Osteitis albuminosa is included as a cause in most classifications and discussions of bone cyst and fibrocystic disease of bone. Beck,[51] Tietze,[52] Silver,[53] Felten and Stoltzenberg,[54] von Bergmann,[55] Bolognesi,[56] Meyerding[57] and Ashhurst, Bromer and White,[58] among others, concerned themselves with this problem. In occasional cases reported by some of them the infectious character is evident, as in Ehrich's case, and in others it may be strongly suspected. Phemister and Gordon[59] stated the belief that infection is a major cause of "solitary bone cysts" and that more careful bacteriologic studies may prove infectious many conditions now classified otherwise. It is not the purpose here to enter into a discussion of cysts, benign or malignant, of bone. It is intended rather to point out the part which attenuated bacterial infections may play in their causation. Exclusion of these cases of osteitis albuminosa from general discussions of cystic changes in bone would unburden to some extent the literature dealing with "genuine bony cysts" (Tietze[52]) and other cystic diseases of bone.

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51. Beck, C.: Osseous Cysts of the Tibia, Am. J. M. Sc. **121**:667, 1901.
52. Tietze, A.: Die Knochenzysten, Ergebn. d. Chir. u. Orthop. **2**:32, 1911.
53. Silver, D.: The So-Called Benign Cyst of the Bones, Am. J. Orthop. Surg. **9**:563 (May) 1912.
54. Felten, R., and Stoltzenberg, F.: Traumatische solitäre Knochenzysten, Ztschr. f. orthop. Chir. **30**:430, 1912.
55. von Bergmann, G.: Zur Kasuistik von Cysten in den langen Röhrenknochen, Deutsche Ztschr. f. Chir. **124**:1 (Sept.) 1913.
56. Bolognesi, J.: Ueber die Pathogenese der sogenannten Knochenzysten, Deutsche Ztschr. f. Chir. **131**:382 (Sept.) 1914.
57. Meyerding, H.: Cystic and Fibrocystic Disease of Long Bones, Am. J. Orthop. Surg. **16**:253 (Sept.) 1918.
58. Ashhurst, A.; Bromer, R., and White, C.: Cystic Disease of the Bones, Arch. Surg. **6**:661 (May) 1923.
59. Phemister, D. B., and Gordon, J. E.: The Etiology of Solitary Bone Cyst, J. A. M. A. **87**:1429 (Oct. 30) 1926.

SUMMARY

A form of osteoperiostitis first noted by Ollier is described. It is an infection caused by the pathogenic organisms usual in ordinary forms of superficial and deep osseous infection, but of low virulence. The lesions in this form are usually superficial and localized but occasionally of deeper origin.

Trauma, though it plays a part in causing this form of osseous infection, is not to be regarded as the primary or sole etiologic factor. Inability to demonstrate the presence of micro-organisms in the lesions does not establish their absence.

The indolent character of the process and the absence of the usual signs of infection in cases of osteoperiostitis albuminosa may cause diagnostic difficulties. Tuberculosis, when it is in question, can usually be recognized by roentgenologic study, by examination of tissue or by animal inoculation. Malignant growths have at times been simulated by the history of gradual onset and progression and by roentgenographic characteristics. Confusion in diagnosis has occurred in cases of osteoperiostitis albuminosa with accumulations of synovia-like exudate when these accumulations were located in regions ordinarily the seat of ganglions and cysts. Aspiration and roentgen examination may clarify the picture.

The lesions are mild and benign. Simple incision with adequate drainage and removal of sequestrums, whether or not the cystlike structures are removed, suffices usually for recovery within a short time.

The centrally located lesion of osteomyelitis albuminosa should be distinguished from the "genuine bony cyst."

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TIC DOULOUREUX

PARTIAL SECTION OF THE ROOT OF THE FIFTH CRANIAL NERVE; A COMPARISON OF THE SUBTEMPORAL AND CEREBELLAR APPROACHES FROM SURGICAL AND PHYSIOLOGIC STANDPOINTS

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The development of a surgical cure for tic douloureux presents one of the most brilliant chapters in the history of surgery of the nervous system and indicates step by step how surely and definitely progress may be made.[1]

At the present time there are two cleancut operative procedures by which the sensory root of the fifth nerve may be sectioned partially or entirely, producing a cure of the hideous malady and entailing a negligible mortality in experienced hands.

There is some controversy concerning the relative merits of the two procedures, and I felt the need of a comparative study by one person.

Many interesting and important problems arise, both theoretic and practical, when an incomplete section of the fifth root is considered. I wish to suggest possible explanations for certain paradoxes and discrepancies in results and to report that my experiences have confirmed the fact that "tic douloureux," at least that involving the second and third branch distribution, can be cured surgically with losses in all modalities of sensation so trivial as to be undetected by the patient.

This great stride in the perfection of an ideal in surgery adds the final achievement to the triumphs of those persevering pioneers who directed a courageous and relentless attack on a field no larger than an inch in diameter for over forty years.

From the Department of Surgery of the College of Medicine, State University of Iowa.

1. (*a*) Frazier, C. H.: Radical Operations for Major Trigeminal Neuralgia, J. A. M. A. **96**:913-916 (March 21) 1931. (*b*) Dandy, W. E.: Operation for the Cure of Tic Douloureux: Partial Section of the Sensory Root at the Pons, Arch. Surg. **18**:687-734 (Feb.) 1929. (*c*) Lewis, D.: Practice of Surgery, Hagerstown, Md., W. F. Prior Company, Inc., 1932, vol. 12.

COMPARISON OF THE APPROACHES FROM A SURGICAL STANDPOINT

SUBTEMPORAL APPROACH

The subtemporal approach to the root of the fifth cranial nerve is almost universally used. The essentials in operative technic have been worked out in detail and to a highly successful end by Frazier,[1a] Adson,[2] Stookey[3] and others.

A linear incision is made in the temporal region beginning at a point directly above and about 4 cm. from the superior margin of the pinna and is carried forward to the zygomatic process about a finger's breadth anterior to the external auditory meatus. The line of intersection of a transverse and a coronal plane passed through the latter point will usually pass through the foramen spinosum. In other words, the trunk of the middle meningeal artery, which is the most important point in the procedure, will be straight in from a point a finger's breadth anterior to the external auditory meatus. The wound is spread by a suitable self-retaining retractor and a bony defect about 5 cm. in diameter is prepared. The dura is gently and slowly elevated to the foramen spinosum and the meningeal artery is dispensed with either by ligating it or by plugging the foramen and cutting. The mandibular branch of the fifth nerve as it disappears into the foramen ovale is regularly found just anterior and mesial to the foramen spinosum. After carefully loosening the point of adherence of the dura to the third branch, the former can be stripped from the lateral face of the semilunar ganglion by pushing it firmly upward with a small solid cotton ball fixed in a hemostat. The pulsating arachnoid membrane which is reflected over the posterior aspect of the ganglion and root comes into view. When the arachnoid membrane is incised the fan-shaped sensory root is well exposed. The motor root is a single large distinct filament; it is concealed from view, since it courses mesially to the sensory root and superoinferiorly. The inferior filaments of the sensory root are sectioned as extensively as the occasion may demand.

CEREBELLAR APPROACH

The cerebellar approach was developed by Dandy[4] and has been almost exclusively used by him. He has listed the following advantages of the approach: (1) There is never corneal disturbance as the result of the operation; (2) there is never injury of the motor branch; (3)

2. Adson, A. W.: The Diagnosis and Surgical Treatment of Trigeminal Neuralgia, Ann. Otol., Rhin. & Laryng. **35**:601-631 (Sept.) 1926.

3. Stookey, B.: Differential Section of the Trigeminal Root in the Surgical Treatment of Trigeminal Neuralgia, Ann. Surg. **87**:172-178 (Feb.) 1928.

4. Dandy, W. E.: The Treatment of Trigeminal Neuralgia by the Cerebellar Route, Ann. Surg. **96**:787-795 (Oct.) 1932.

sensation may be preserved everywhere intact or nearly so; (4) facial paralysis is absent; (5) the possibility of hemiplegia, aphasia and subsequent epilepsy is absent; and (6) an unsuspected tumor about the fifth root will be brought into view (an unsuspected tumor of the cerebellopontile angle has been found in 5 per cent of Dandy's cases).

Technic of the Cerebellar Approach.—The incision is made as shown by Dandy,[4] the object being to provide an exposure as far superior and lateral in the cerebellar fossa as is feasible. A defect in bone about the size of a silver half-dollar is made, the opening being carried laterally as far as the mastoid will permit and superiorly so as barely to expose the transverse sinus. This allows the surgeon, when the dura is reflected, the optimum exposure of the angle made by the tentorium and the petrous bone, and is a very important part of the exposure. I prefer to reflect a circular flap of dura with a small hinge at the most lateral aspect of the transverse sinus. This provides an easier closure than if the reflection were made by crisscross incisions. The cisterna magna is brought into view by depressing the cerebellar hemisphere and is ruptured with a suitable instrument to allow the escape of fluid and to provide room. One may now begin the retraction of the cerebellum laterally at its anterosuperior angle, or one may begin the retraction a little lower directing it superiorly and mesially. In any case, I prefer to work toward the tentorium-petrous angle and proceed directly down to its mesial aspect where the fifth root is to be found. This precaution gives the operator the maximum clearance of the seventh and eighth nerves. The lateral cistern is carefully torn, and the petrous veins are cauterized. It is important to progress patiently here so as to cauterize the intact veins before they are ruptured. The electrocautery should not be too forceful, since the heat produced in the proximity of the seventh and eighth nerves may prove to be a source of injury. Such an error, which was encountered by me in 1 case, has been obviated to a great extent by modifying the cerebellar retraction as explained. The use of this approach also makes minimal any necessary stretch of the seventh and eighth nerves. The seventh nerve appears to be more vulnerable than the eighth and will give way under tension long before the latter. One finds, however, that when suitable instruments are used the exposure of the fifth root may be so small that no tension on the seventh and eighth nerves is necessary. When the lateral cistern is opened and the petrous veins are divided, the white fifth root many be seen in the depths of the exposure. A partial or complete section of the sensory root is made as desired. The sensory root is toward the operator at a safe enough distance from the motor root.

Flat moist cotton strips should always lie between the retractor and the cerebellum.

After the lateral cistern has been opened, I progress with a retractor only ¼ inch (0.6 cm.) wide so as to maintain a safe clearance above the seventh and eighth nerves.

The ordinary bayonet forceps has proved too short for satisfactory use in this operation. Since the blades of the longer bayonet forceps provided by the instrument companies are too large, I have had those of the ordinary forceps extended 1 inch (2.5 cm.). Likewise by extension of the handles of a pair of eye muscle scissors a useful instrument

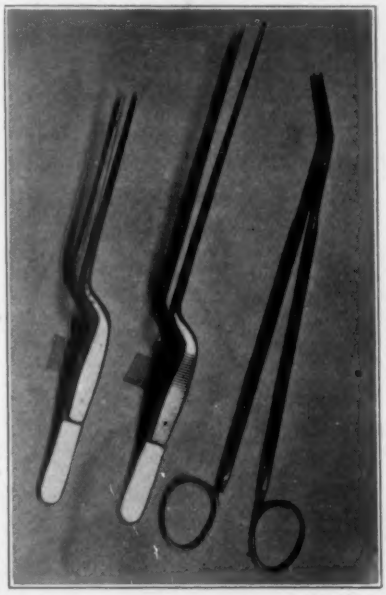

Fig. 1.—Useful instruments for the operation for tic douloureux. The ordinary bayonet forceps has been extended. The handles of a pair of eye muscle scissors have been extended.

was made for cutting the cauterized petrous veins (fig. 1). The scissors were at first intended for cutting the nerve root, because it appears that no matter how sharp a hook knife may be a certain amount of avulsion of the tender root may accompany the attempt at cutting. The scissors proved difficult to manage, however, because through such a small opening stereoscopic vision is hardly possible; hence the difficulty in placing the points of the scissors accurately.

Dandy [4] proposed that the desired amount of the nerve should be picked up with the bayonet forceps and severed by application of the electrocautery.

I have now designed a guillotine knife the shaft of which is a lumbar puncture needle (fig. 2). The hooked end is placed to the desired depth under the root, and the blade is driven home, making a clean, accurate cut with no undue injury to the nerve. Stereoscopic vision is not necessary and the size of the exposure may be minimal.[5]

I have noted the possibility and the probability of injuring the root at operation more than was intended. I have had 2 cases in which this occurred. The reason for it is that the tender root will often be avulsed at the pons more easily than it will be divided. (I have confirmed this a number of times at the necropsy table.) It may still occur even though one uses a sharp hook knife, so that if one attempts to section half the nerve root with a hook knife one may cause avulsion of the entire root and not be aware of it. At any rate it is certainly possible to cause a greater injury than was intended. Particularly if the root is sectioned by the subtemporal route there will be less chance of one's being cognizant of the total injury than if the root is sectioned at the pons. I feel confident that this may explain a great discrepancy that has existed in the findings after a supposed partial section. Hence the greater need for instruments that will obviate such an outcome.

Another important part of the equipment for this operation is the means of illumination. It is absolutely necessary for the operator to see well what he is doing. Lighted retractors which are on the market at present are entirely impractical. They occupy too much space; moreover, should fluid and blood obscure the light they would leave the operator without illumination at the time he needs it most. A head lamp is the preferable source of illumination. Having failed to find a head lamp satisfactory for this purpose, I set out to make one. The result has proved so useful that I feel it worth while to incorporate a description of the lamp here.

The essential requirement of such a lamp is that it throw a small, bright spotlight into the operative field. Low voltage lamps are superior. A full size, 2 cell, adjustable focus flashlight is dismantled and the head is cut off on a bevel that will give the proper tilt of the reflector (fig. 3).

One connector is present in the head, but a second must be soldered into the head to provide contact with the center connector of the bulb. Wire leads are soldered to the connectors, and the head is backed by a piece of stiff cardboard or other suitable material. Any form of celluloid-acetone glue will suffice to fix the piece. A 9 volt flashlight bulb is ideal, and the reflector is adjusted to make the spotlight satisfactory.

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5. This instrument was milled by Mr. A. P. Freund, Mechanician, Pharmacology and Physiology Shop, State University of Iowa. Duplicates may be obtained from him.

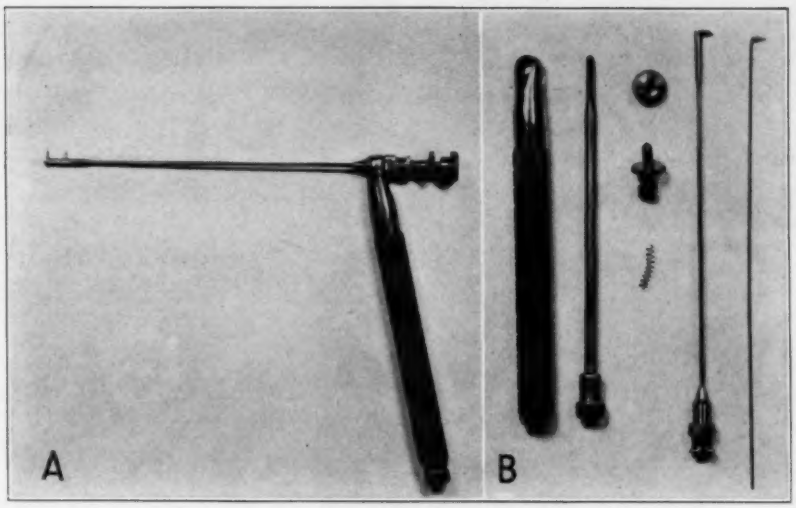

Fig. 2.—Guillotine knife. *A*, knife assembled. The tiny blade moves freely into a slotted guard when the thumb button is pressed. The blade returns by spring action. The blade was designed so that its length would be equal to only half the width of the average sensory root at the pons. *B*, parts of the instrument. Left to right: handle; set screw by means of which the blade shaft may be rotated at any angle to the handle; thumb screw which fixes the blade rod; blade rod guide; spring; blade shaft with terminal slotted guard (made from lumbar puncture needle); blade, made from piano wire. This may be easily and inexpensively renewed from time to time if necessary). The instrument should be sterilized in the autoclave. The drawing below illustrates the use of the instrument. The insert shows the section completed.

This light will remain concentrated at varying distances. A simple arrangement is to cover the bulb socket with a small section of snug-fitting rubber tubing of such a size that the reflector may be snugly twisted over it. The reflector may then be adjusted properly and glued to the rubber sleeve.

If the source of current is the ordinary 110 volt circuit, a 9 volt transformer must be interposed. I found that the 9 volt transformers supplied with toy electric trains are satisfactory and inexpensive. They may be obtained separately. There is no need of covering the reflector. If it tarnishes it may be polished, or the whole piece may be preserved in a case when not in use.

The lamp may be fastened to wide elastic tape made to fit the operator's head. The wire goes over the head and is fastened to the elastic

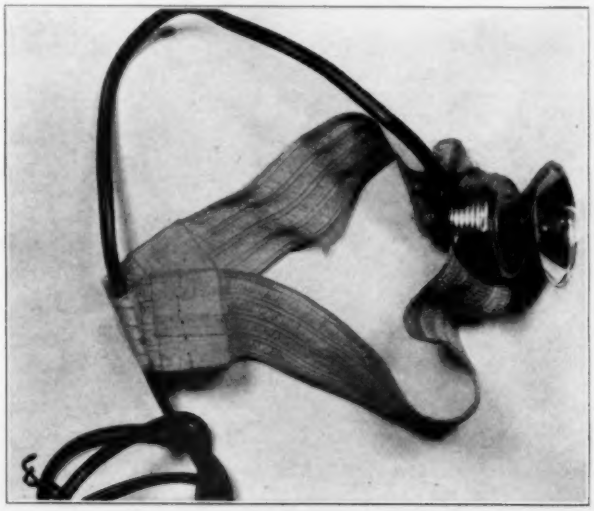

Fig. 3.—A useful head lamp, providing the proper illumination for operating through small deep exposures. The lamp is described in the text.

in the back. After the head piece is glued to the tape a thread is placed through the two holes in the head piece and through the backing and the tape, so as to provide additional security against the lamp's falling from the tape.

The finished product is small and light, does not become hot, is easily applied during the operation and is inexpensive. It fulfils exactly the needs in illumination for this procedure.

ADVANTAGES AND DISADVANTAGES OF THE TWO METHODS OF EXPOSURE FROM A SURGICAL STANDPOINT

The incision through skin, muscle and bone is quicker, easier and attended with less bleeding in the subtemporal exposure. Facial palsy

occasionally occurs with the subtemporal exposure and has been attributed to an indirect injury of the geniculate ganglion through an injury to the petrosal nerves. When this has occurred in my cases it has disappeared later. I have at times felt it might be due to injury or section of the peripheral branches of the seventh nerve, but its general absence after decompressions made through similar incisions obviates such a possibility.

In respect to the cerebellar approach, although with a reasonable amount of skill one should be able to manipulate without injuring the seventh nerve, it cannot be gainsaid that this nerve is always in a vulnerable spot. If it tears apart, the injury is permanent and irreparable, save for spinofacial anastomosis.

The subtemporal approach has the advantage of being largely but not entirely extradural.

I have found bleeding to be more troublesome with the subtemporal approach than with the cerebellar approach. Stripping the dura may be attended in certain cases by venous oozing that requires much time and patience to control, particularly since it is often impossible to find the source of the bleeding. With the cerebellar approach, provided the petrosal veins are properly cared for (and I have encountered no difficulty at this point) the intracranial portion of this operation may be entirely bloodless. On the whole, the middle meningeal artery and the petrosal veins are about equally matched as hazards in the two approaches.

I have had no difficulty in differentiating and preserving the motor root in the temporal approach, although it is necessary at times to manipulate it in separating it from the sensory filaments. No manipulation is necessary in the cerebellar approach.

Occasionally a thin, adherent dura which repeatedly tears constitutes a distinct disadvantage in the temporal exposure, and if the dura tears at the ganglion and is unusually adherent to it the operator may be completely defeated. The tendency in such a situation is not to give up until the operator is exhausted and perhaps an unnecessary amount of damage has been done to the patient. Such an ultimate defeat is not so likely in a well directed cerebellar approach. It may be that previous injections of alcohol cause the dura to become more firmly adherent to the ganglion.

In the cerebellar exposure the occipital nerves to the scalp are sectioned, and there results a degree of numbness in their distribution. This is a criticism of the cerebellar approach, but a minor one, because it is only minimally disturbing to the patient and with proper anatomic closure is not permanent.

Dandy [4] states that he does not carry his incision far enough to include the great occipital nerve.

The first incisions made by me, such as that shown in figure 9, were more extensive than was necessary. The incision has been reduced to the size illustrated in figure 11. This incision easily avoids the great occipital nerve and it has proved no more difficult to reach the cerebellar cistern and complete the operation with this incision than through a larger exposure.

At the termination of a subtemporal approach the degree of dural and osseous oozing will often, though not always, make it advisable, as Adson has maintained, to leave a gauze pack planted against the ganglion. The subsequent removal of this pack is not altogether pleasant for either the surgeon or the patient, and the use of drainage material is always precarious in surgical operation on the brain. I have never seen any indication for employing drainage material or packs in making the cerebellar approach.

In conclusion, speaking from a surgical standpoint, I feel that the odds are in favor of the cerebellar approach as being a finer, more bloodless and more dependable operation. It requires, however, a greater measure of technical skill and experience in the cerebellar fossa and decidedly more care.

ETIOLOGY OF TIC DOULOUREUX

With respect to the cause of tic douloureux, it may be said that any impression at the present time is purely hypothetic. The locus operandi has variously been placed at the receptor of the sensory nerve, the branches, the ganglion, the root, the bulbar contingent and even the thalamus. No incontrovertible evidence has been brought forth in any case, and objective pathologic changes have been uniformly absent.[6] One clinical fact seems well established, however, which is that when the end organ is destroyed or anesthetized, particularly in the region of the trigger zones, the crises cease to occur, and when the function of the end organ is restored the painful crises reappear. In this light I feel it worth while to recall the experiments of Davis and Pollock.[7] When the superior cervical ganglion is stimulated in the cat under the influence of bulbocapnine, the animal exhibits definite symptoms of severe pain in the

6. W. E. Dandy (Concerning the Cause of Trigeminal Neuralgia, Am. J. Surg. **24**:447-455 [May] 1934) has reported a high incidence (60 per cent) of gross pathologic changes uncovered by the cerebellar exposure which he felt were of etiologic importance. Five and six-tenths per cent of the lesions encountered were tumors of the cerebellopontile angle.

7. Davis, L., and Pollock, L. J.: The Role of the Sympathetic Nervous System in the Production of Pain in the Head, Arch. Neurol. & Psychiat. **27**: 282-293 (Feb.) 1932.

head. The pain lasts only during the period of stimulation and occurs whether the proximal cervical chain is intact or not. Section of the anterior and posterior spinal roots from the first to the twelfth thoracic does not abolish the phenomenon, but section of the fifth root in addition does abolish it. Davis and Pollock [7] concluded that something was taking place at the sympathetic terminals that was relayed through the afferent fibers of the fifth nerve and interpreted as pain. Stimulation of the cervical chain proximal to the superior cervical ganglion had the effect only of dilating the ipsilateral pupil and causing movements of the nictitating membrane. With the cooperation of Dr. Tracy Putnam I had the opportunity at the Boston City Hospital of confirming these results so far as stimulation of the superior cervical ganglion is concerned, but no sensory roots were sectioned. To my knowledge there is no evidence to show whether this pain is instigated at the receptor or at the ganglion of the fifth nerve.

The abolition of visceral pain by section of the abdominal sympathetic nerves has been accomplished by Archibald [8] and Scrimger.[9]

In short, it appears to be established that there do exist afferent visceral fibers that mediate pain, and it is possible that they retain their identity to the thalamus.

It is possible that the pain of tic douloureux is mediated by similar fibers coursing along with but anatomically distinct from the cerebrospinal fibers of the fifth nerve. This would help to explain the paradoxic results obtained in the cure of tic douloureux by partial section of the fifth root. Such a hypothesis is strongly suggested because the paroxysms are unlike pain which is known to be mediated by the cerebrospinal afferent nerve fibers and do closely simulate the excruciating visceral paroxysms, such as gallbladder and ureteral colic, and, if the comparison is permissible, tabetic crises. Moreover, the exciting factors, such as stroking the skin and cold drafts, are not stimuli ordinarily associated with the initiation of pain which is transmitted by cerebrospinal afferent fibers.

It is not to be implied that efferent cervical sympathetic nerve fibers are responsible for tic douloureux, but these facts do suggest that the pain of tic douloureux and the pain shown by the animals mentioned may be mediated by afferent sympathetic nerves through the fifth nerve.

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8. Archibald, E.: Effect of Sympathectomy upon the Pain of Organic Disease of the Arteries of the Lower Limbs and for Obscure Abdominal Pain, Ann. Surg. **88**:499-509 (Sept.) 1928.

9. Scrimger, F. A. C.: On the Possibility of Relieving Abdominal Pain by Section of Sympathetic Rami Communicantes, Canad. M. A. J. **21**:184-189 (Aug.) 1929.

RESULTS OF PARTIAL SECTION OF THE ROOT OF THE FIFTH NERVE AND THEIR THEORETIC EXPLANATION

There has been considerable controversy concerning the all-important arrangement of fibers in the root of the fifth nerve and their relation to those of the peripheral branches. On clinical grounds there seems to be a consensus that some topographic relation is maintained in the ganglion and the root so that the upper, middle and lower thirds of the root correspond roughly with the first, second and third peripheral divisions of the nerve.[10] Opposition to this concept has been on anatomic grounds.[11]

Davis and Haven [12] studied macroscopically and microscopically the root fibers and the bulbar fibers, after degeneration, from various sections in the cat. In this animal they found the root to be rotated so that the ophthalmic fibers, which are superior just proximal to the ganglion, become inferior as the root enters the pons. Hence a section of the superior half of the nerve just proximal to the ganglion gives the same degeneration picture in the spinal root as does a section of the inferior half of the root as it enters the pons. They stated that the root is rotated in a like manner in man. Clinical results, however, do not bear this out.[13] They found in the degeneration experiments that the fibers in the spinal root of the cat are so disposed that those from the ophthalmic nerve are ventral and those from the mandibular nerve are dorsal. In either case degeneration is evident throughout the entire length of the spinal root. This indicates that the topographic relationship in the root maintains itself even in the brain stem. Spiller [14] made these observations as early as 1901, and Bregman [15] in 1892, with rabbits. The five authors were in agreement on the findings.

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10. Frazier, C. H.: Subtotal Resection of Sensory Root for Relief of Major Trigeminal Neuralgia, Arch. Neurol. & Psychiat. **13**:378-384 (March) 1925. Frazier, C. H., and Whitehead, E.: Morphology of the Gasserian Ganglion, Brain **48**:458-475 (Dec.) 1925. Stookey.[3]

11. Van Nouhuys, F.: The Anatomy of the Gasserian Ganglion: Its Relation to Tic Douloureux, Arch. Surg. **24**:451-457 (March) 1932.

12. Davis, L., and Haven, H. A.: Surgical Anatomy of the Sensory Root of the Trigeminal Nerve, Arch. Neurol. & Psychiat. **29**:1-15 (Jan.) 1933.

13. My observations of the nerve root at the necropsy table have convinced me that the rotation of the root from ganglion to pons is about 20 to 30 degrees but certainly not of the magnitude of 180 degrees.

14. Spiller, W. G., and Frazier, C. H.: The Division of the Sensory Root of the Trigeminus for the Relief of Tic Douloureux: An Experimental, Pathological and Clinical Study, with a Preliminary Report of One Surgically Successful Case, Univ. Pennsylvania M. Bull. **14**:341 (Dec.) 1901; Philadelphia M. J. **8**:1039, 1901.

15. Bregman, E.: Ueber experimentelle aufsteigende Degeneration motorischer und sensibler Hirnnerven, Arb. a. d. Inst. f. Anat. u. Physiol. **1**:73-97, 1892.

Davis and Haven [12] after experiments in teasing the human nerve root pointed out a liberal anastomosis between the macroscopic filaments. Microscopically they were unable to find a topographic segregation of small and large fibers in the root. Spiller,[14] however, logically pointed out that physiologic implications may not always be drawn accurately from anatomic findings.

On clinical grounds the following observations would seem incontrovertible:

1. As one sections the root from below upward, whether at the pons or at the ganglion, the loss of sensation progresses from the lowermost distribution in the face upward and from the midsagittal plane laterally. (Observations made by the department of neurology and by myself after partial sections of the fifth root have not exhibited losses in sensation with as cleancut boundaries as have been indicated in Frazier's reports.[1a] In fact, when losses in various modalities of sensation could be demonstrated it has been my impression that they conform more to a segmental or nuclear distribution than to a peripheral branch distribution.)

Although degeneration experiments have demonstrated the ventrodorsal disposition of fibers in the spinal root, no evidence, save in cases of syringobulbia [16] has been forthcoming concerning the disposition in the long axis of the spinal root. Spiller has expressed the view that the descending spinal root represents pain and temperature sensation and that there is evidence to show that the sensations of pain, heat and cold may be to some extent anatomically segregated, as is the case in the spinothalamic tracts. It appears that sensory distribution from the midsagittal plane of the face laterally is represented in the long axis of the spinal root and that the fibers representing the most lateral distribution in the face extend farthest caudad in the spinal root.

It thus appears that one of the differences in the results obtained by cutting a peripheral branch and by partially cutting the nerve root is that in the latter a combined branch and segmental loss obtains.

2. Section of the inferior half of the root may eliminate the pain crises of tic douloureux, at least in the second and third branches, and loss of any modality of sensation in the face may be so insignificant as to be unnoticeable by the patient and to require most careful examination for its detection. If the loss is detectable, it involves sensation to pain more than to light touch and is diffusely distributed over an area rather than bounded by cleancut borders.

I have verified this statement so far as the cerebellar approach is concerned, but I am not wholly prepared to make the same statement for

16. (*a*) Grinker, R. R.: Neurology, Springfield, Ill., Charles C. Thomas, Publisher, 1934, p. 330. (*b*) Jelliffe, S. E., and White, W. A.: Diseases of the Nervous System, ed. 4, Philadelphia, Lea & Febiger, 1923, plate X.

the subtemporal approach. The partial sections made by the subtemporal approach have been extended much farther than half the length of the nerve. In fact, until now only one macroscopic filament has been left in the upper aspect of the root. This was done through fear of an insufficient operation. The remaining fasciculus proved adequate to supply the ophthalmic distribution and corneal sensation, with no detectable loss in that field.

I should like to suggest the following explanation to account for the incommensurate retention of sensation after a partial section of the sensory root. It should be remembered that the fifth nerve is a single nerve which peripherally has been split three ways but that this peripheral division should in no way destroy the possibilities of overlap that characterize the sensory domain. It is not unlikely that the plan of innervation is that indicated in figure 4 *A*. The uppermost neurons (*A*) send dendrites largely to the ophthalmic distribution (*O*). The next lower neurons (*B*) innervate the ophthalmic and maxillary regions. The middle neurons (*C*) send dendrites to all three divisions, and the still lower neurons (*D*), to the maxillary and mandibular regions. The lowermost neurons (*E*) largely innervate the mandibular region.

If only the *E* fibers are sectioned, little loss will be expected even in the mandibular division. If *D* and *E* (probably representing the lower third of the root) are sectioned, there will still not be a total loss even in the mandibular region. The diagram can thus be worked out for various sections and is the simplest possible diagrammatic representation of the scheme of innervation. It is likely that the three way distribution of the dendrites is far more extensive for each neuron than is indicated in the diagram. This plan of overlap would adequately explain how the nervous system might conserve the number of axons necessary to innervate a broad surface of skin. This will also explain the phenomena of referred sensations demonstrated in case 1 in the following manner: First, consider the simplest possible plan shown diagrammatically in figure 4 *B*, of three neurons each having independent dendrites and receptors as well as receptors in close contiguity with their fellows. If receptor X_1 is stimulated, the stimulus will be transmitted only by the axon *X*. If the locus of stimulation is a point where X_2 and Y_1 are contiguous,, the stimulus will be transmitted by axons *X* and *Y*. If at Y_2, *Y* alone will carry the impulse. In this manner, such a plan as shown in the diagram provides five different combinations or patterns of stimulus transmission, or combinations equal to $2N - 1$, when *N* is the number of neurons. This may be called a combination of first order.

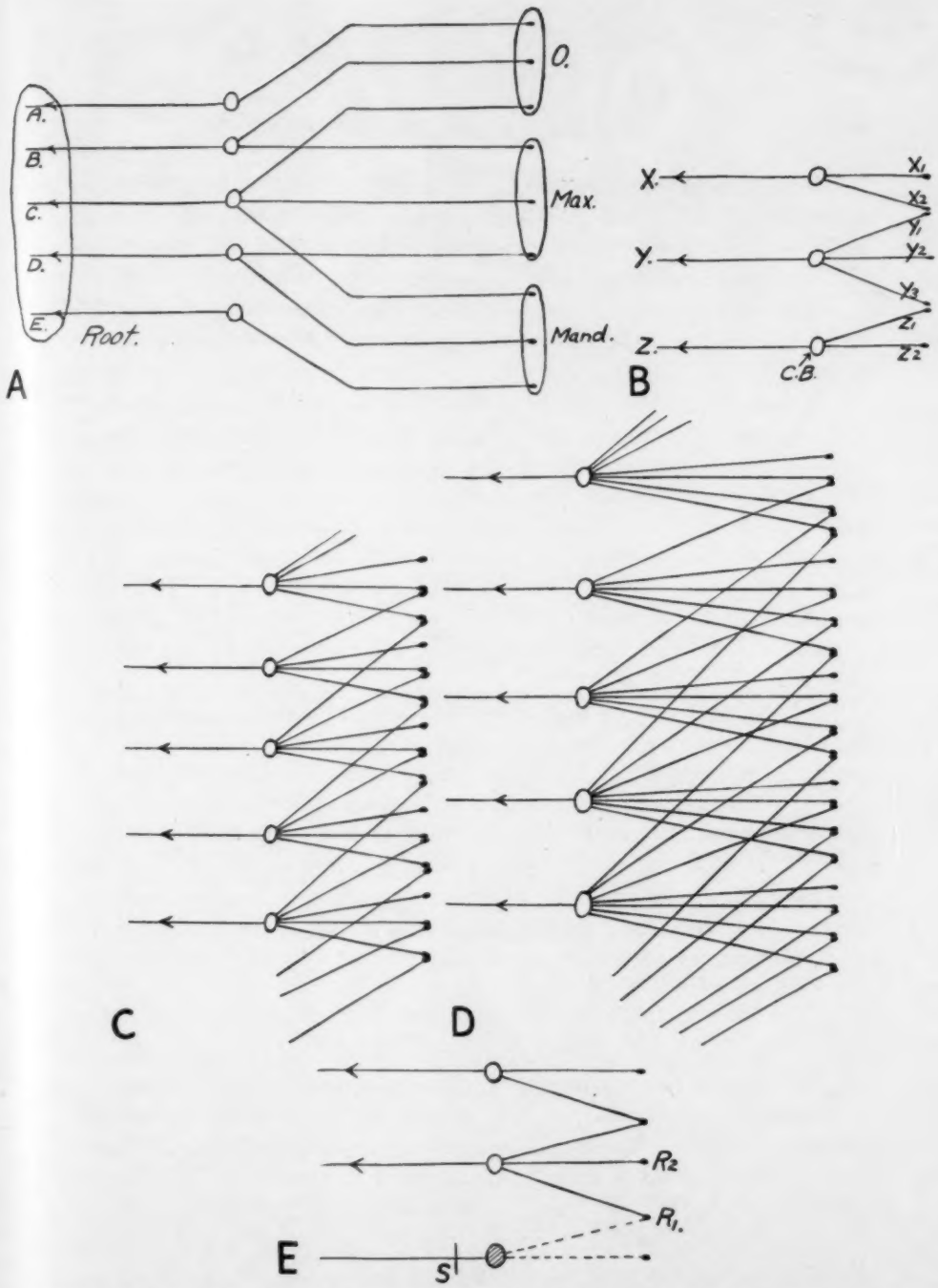

Fig. 4.—*A*, diagrammatic representation of a hypothetic plan of overlap in the sensory fifth nerve. *A-E*, axons; *O*, *max.*, *mand.*, ophthalmic, maxillary and mandibular branches of the fifth nerve (see explanation in text). *B*, diagrammatic representation of a hypothetic plan of sensory innervation of the skin, illustrating the simplest plan of neuron combinations. *X*, *Y and Z*, axons; X_1, free receptor for *X*; X_2 and Y_1, contiguous receptors or single receptor for *X* and *Y*; Y_2, free receptor for *Y*, etc.; *C. B.*, body of cell. The possible axon pattern combinations in this diagram equals $2N-1$, *N* being the number of neurons. (See explanation in text.) *C*, diagram illustrating a combination of each neuron with four of its fellows, a plan of second order. The number of axon pattern combinations possible in this diagram equal $3N-3$. *D*, diagram illustrating a combination of each neuron with six of its fellows, a plan of third order. The number of possible axon combinations in this diagram equals $4N-6$. *E*, diagram of the simplest plan to illustrate the possible mechanism of the phenomenon of referred sensation. *S*, section of axon; R_1, disassociated receptor; R_2, free receptor of middle neuron. (See text for explanation.) This concept will adequately account for the phenomena of spread and hyperesthesia.

If one assumes a more complex arrangement, such as that shown in figure 4 *C*, in which each neuron has contiguous receptors with four of its fellows, the possible axon combinations will be $3N - 3$, a combination of second order.

If, as in figure 4 *D*, each neuron has contiguous receptors with six of its fellows, the possible combinations will be $4N - 6$, a combination of third order.

That is, 100 axons could supply about 400 skin loci, each of which could be discriminated from the other, *provided* one accepts the proposition that such axonal patterns of afferent stimuli could provide a mechanism of integration in terms of localization. It seems to me that some such plan must obtain to account anatomically for the evident conservation of axons in the nerve roots and in the spinal cord.

So far as the receptors are concerned, it is not too imaginative to assume that the dendrites of several neurons take origin from a single receptor rather than from contiguous receptors as indicated in the diagram.

The phenomenon of referred sensation, as exhibited in case 1, may then be explained as follows:

If, as in figure 4 *E* (the simplest possible diagram), an axon is severed at *S*, all the dendrites indicated by dotted lines cease to function, and hence, with the standard pattern disrupted, if a stimulus is applied to receptor R_1 it can only be interpreted as having been applied to the free receptor, R_2. Hence, the distance from the actual stimulus to the point of reference may give a rough indication of the magnitude of the territory innervated by a single neuron.

WHY "TIC" SHOULD BE ELIMINATED WHEN SENSATION IN GENERAL HAS BEEN SO LITTLE DISTURBED

Two possible reasons for the elimination of the "tic" are suggested: First, one may be dealing with a pain which is mediated by afferent sympathetic nerves, as pointed out in the section on etiologic considerations, and it may be that the involved fibers are cut in the procedure. Second, the trigger zones may be the sole regions of excitation of the pain. Indeed, if such regions are locally anesthetized the pain is abolished until the anesthesia disappears.

The trigger zones are almost always situated in the gums, in the buccal mucosa or about the lips or the side of the nose; that is, they are usually located within the innermost segment of the distribution of the fifth nerve.

When the lowermost fibers of the root are sectioned, it is this segment that is most involved, particularly with respect to pain sensation, and the denervation may be just sufficient to abolish the abnormal reaction of the trigger zones.

COMPARISON OF THE TWO APPROACHES FROM A PHYSIOLOGIC STANDPOINT

Corneal Ulcer.—I have been spared the occurrence of corneal ulceration in all my cases of partial section when corneal sensation has been preserved, whether the approach was subtemporal or cerebellar. A corneal ulcer has developed in 1 case for each exposure when the division of the sensory root was complete and corneal sensation was lost. It is felt that loss in corneal innervation is the important feature, regardless of the approach. An early lesion is probably on a trophic basis, as is herpes of the skin, though the cornea may subsequently be inadvertently injured because of the anesthesia.

REPORT OF CASES [17]

SUBTEMPORAL EXPOSURES

CASE 1.—B. W., a white woman aged 50, was referred to me by Dr. George D. Callahan, of Iowa City, in May 1936. She dated the onset of her attacks to 1920, after the extraction of an abscessed tooth. The pain was sharp and stabbing and lasted from three to four seconds. It began anterior to the right ear and radiated to the mouth. In 1928 an attempted operation by the subtemporal exposure was unsuccessful. After the operation she noticed that part of the right cheek was numb. There was a transient palsy of the sixth nerve on the right side. In less than a month the painful seizures had returned.

On this admission to the hospital, she stated that the attacks had become so frequent and severe that she had been in constant agony and unable to sleep. The pain started in the right malar region and radiated to the right buccal angle. The right half of the tongue was severely involved and appeared to be a trigger zone. Excitement, worry, nervousness, a draft of air, chewing and swallowing were exciting factors. On examination a small portion of the anterior part of the right cheek revealed about a 20 per cent loss of sensation to light touch and to pain. By a subtemporal approach on the right side the sensory root of the fifth nerve was exposed, and all its fibers were sectioned with the exception of the most superior fasciculus. The motor root was identified and spared. The wound healed uneventfully, and pain has remained absent to the present time (ten months).

Postoperative studies (fig. 5) gave striking results in regard to the sensation remaining. Even more interesting is the fact that the patient referred the touch points to locations quite wide of the points of actual contact as indicated in the diagram. Daily tests were carefully made with her eyes closed, and the findings remained consistent. She was highly cooperative, and I feel that her responses were dependable. The answers were not prompted in any way. A hypothetic explanation of this phenomenon has been given.

The impression was gained at the time of operation that the surgeon operating in 1928 had only partially injured the maxillary peripheral division of the nerve.

17. The operations here reported, representative of both approaches, were well controlled as to observations made at the time of operation, and I feel that there was no trauma to the nerve other than the intended section. The postoperative studies were checked repeatedly by several examiners.

Case 2.—L. D., a white woman aged 55, was referred to me by Dr. C. B. Busby, of Brooklyn, Iowa, in April 1936.

In March 1935, she had her first "crash" of pain, a terrific paroxysm of short duration over the left maxillary region. The attacks occurred four or five times a day. Touching the lower part of the left side of the nose invariably provoked an attack.

She received an injection of alcohol in July 1935, which lessened somewhat the severity, but not the frequency, of the attacks. The trigger zone on the left side of the nose shifted to the upper gums on the left side, and the attacks began to involve the distribution of the left second and third branches, with an

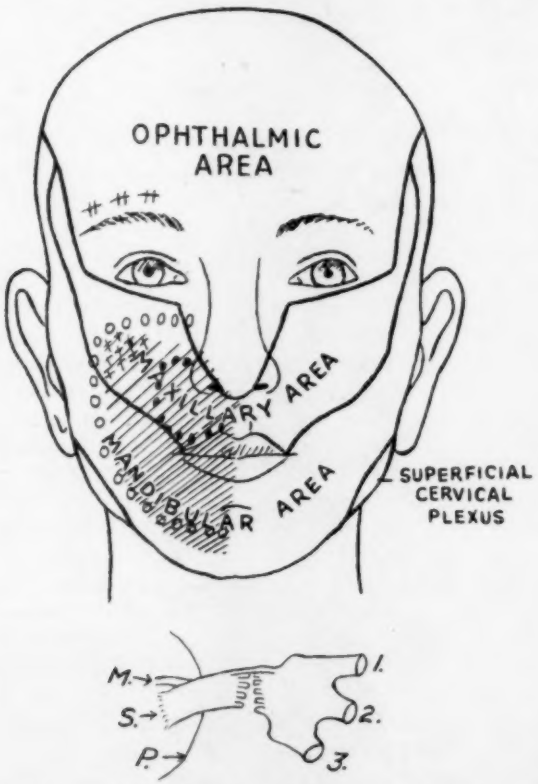

Fig. 5 (case 1).—The single lines mark the area in which the sensation of pain to pinprick was estimated as being about 90 per cent lost. Sensation to touch in this area was about 50 per cent lost. When the patient was touched at the points denoted by the solid black circles she referred the sensation to points denoted by the plain circles. When touched in the region marked by crosses she consistently referred the sensation to the region above the eyebrow marked by double crosses. Herpes developed after the operation on the right side of the lips and chin. The losses of sensation to pain and touch in the buccal mucosa and the right half of the tongue appeared to be about the same as those demonstrated. Corneal sensation and the motor function of the fifth and seventh nerves were intact. No corneal ulcer was present. Subjective numbness was negligible. The drawing at the bottom demonstrates the relative amount of the root sectioned.

occasional involvement of the first division. On rare occasions the right side of the face was involved, but less severely.

On examination there was evidence of a slight loss of sensation to touch and pain over the lower left side of the nose, part of the left cheek and the left side of the upper lip.

After discussing with me the relative merits of total and partial section she chose the partial section, feeling that should the ophthalmic division become too troublesome it could be severed later.

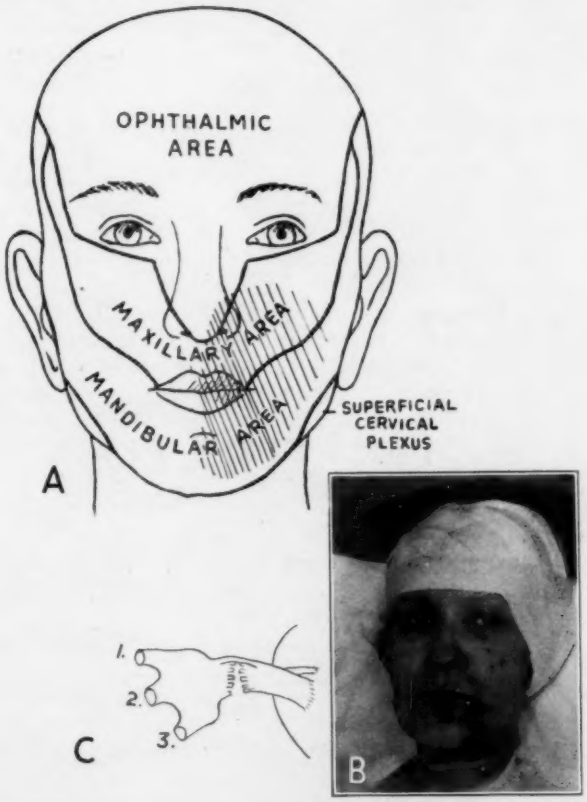

Fig. 6 (case 2).—In the shaded area in *A*, sensation to pinprick was about 90 per cent lost, and to touch was about 50 per cent lost. The cross hatching on the lips represents the area of complete numbness. The buccal mucosa and the left half of tongue presented about the same losses as the regions denoted by the shaded area. *B* shows herpes developed on the lips, the chin and the cheek after the operation, extending about ½ inch across the midline on the chin. Corneal sensation and the function of the motor fifth and seventh nerves were intact. No corneal ulcer was present. Subjective numbness was negligible. *C* demonstrates the relative amount of the root sectioned.

By a left subtemporal exposure the sensory root was exposed, and all its fibers were sectioned except the uppermost fasciculus. The wound healed unevent-

fully. Herpes developed on the left side of the chin, on the left cheek and about the left side of the lips, extending about ½ inch (1.3 cm.) across the midline on the chin.

A sensory loss was found as indicated in figure 6. In this case, which preceded case 1 chronologically, I asked the patient to respond only if she felt the stimulus. I did not ask her to locate it. Hence, information as to referred sensation was not obtained.

The infrequent minor attacks which had involved the ophthalmic division on the left and on the right side were not materially changed after the operation. The major attacks involving the second and third divisions have remained eliminated to the time of writing (one year).

CEREBELLAR APPROACH

CASE 3.—F. B., a white man aged 56, was referred to me by Dr. C. A. Samuelson, of Sheldon, Iowa, in September 1936.

Pain in the right side of the face began in 1911. The attacks lasted for about six months, during which time the patient had some teeth extracted. He was then free of pain until March 1936. He described the pain as an electric shock brought on by cold air, eating or drinking. It was usually confined to the upper lip and the upper part of the cheek on the right side, but occasionally extended to the lower jaw. There was a trigger zone on the lower right side of the nose, the right side of the roof of the mouth and the right side of the upper lip.

The root was exposed through a right cerebellar approach, and slightly more than the lower half was sectioned. The patient's recovery was uneventful except that on the second day after the operation he showed for the first time evidence of slight facial palsy on the right side. This had cleared up, however, at the time of discharge. Studies in sensation revealed the findings shown in figure 7. The sensory losses were so small as to be clinically insignificant.

CASE 4.—F. M., a white man aged 45, was referred to Dr. R. A. Fenton by Dr. L. E. Hooper, of Indianola, Iowa, in August 1936.

In January 1936, pain developed in the right cheek and in both lower jaws. This continued intermittently until June. He had several teeth extracted and was free of pain until August, when pain returned on the right side only. The attacks became more frequent and severe. There was a trigger zone on the right side of the chin, and the pain seemed to involve the second and third branch distribution. He described the pain as giving a feeling "as though a building fell on my face" or "just like a team of horses were pulling my jaw out."

The root of the fifth nerve on the right side was exposed by the cerebellar approach, and half of the root was sectioned. His recovery was uneventful, and sensory studies revealed only moderate diminution in sensation as shown in figure 8. The results were comparable to those in the preceding case. The operative scar and the patient are shown in figure 9. The result from the patient's point of view can be no better expressed than in his own words. When asked if he had noticed that his face felt numb anywhere, he replied in the negative, and then, rubbing his hands over his face, he added, "Doc, if it wasn't for being rid of that awful pain, I wouldn't know I'd been operated on."

CASE 5.—M. D., a white woman aged 72, was referred to me by Dr. B. D. Elliott, of Oskaloosa, Iowa, in January 1937.

Nine years previously she had had a tonsillectomy. An infection of the wound remained for about six weeks. Subsequently, coughing caused a sharp pain in

the right side of the tongue. There was also some loss in control of the tongue, which became somewhat thickened. Touching a spot on the buccal side of the right mandible posteriorly would incite a sharp attack of pain. In 1932 she was given an injection of alcohol, elsewhere, which was repeated in four days. This relieved her attacks for a about a year but induced unpleasant hyperesthesia over the right side of the face. Three more injections of alcohol were given at intervals of three months. The attacks continued to occur more frequently, however, and were severe, appearing to involve the second and third branch distribution on the

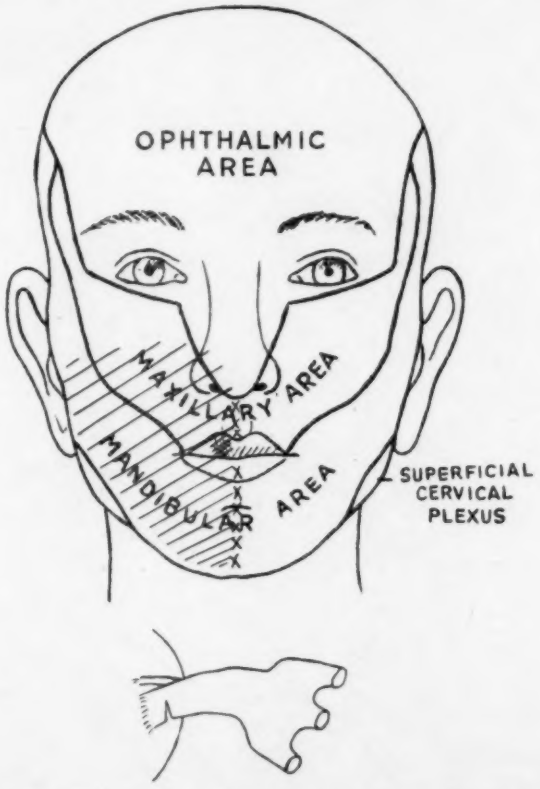

Fig. 7 (case 3).—The shaded area represents the region in which there were about 50 per cent loss of sensation to pinprick and 10 per cent loss of sensation to light touch. Sensation in the tongue and buccal mucosa was about the same. The region denoted by the cross hatching on the lip was completely numb. In the midline, represented by crosses, the patient showed hyperesthesia when a pin was dragged from one side to the other. Herpes developed on the right side of the lips after the operation. Corneal sensation and the function of the motor fifth nerve were intact. There was no corneal ulcer present. Subjective numbness was hardly detectable. A slight facial palsy developed on the second day after the operation, from which the patient had almost completely recovered at the time of discharge. The drawing at the bottom demonstrates the relative amount of the root sectioned.

right. She discovered trigger zones on the right side of the tongue, on the right side of the lower lip and on a spot just lateral to the lip. Touching these zones, chewing or eating anything cold invariably incited the attacks, and she presented a typical picture. The face was held rigid, she talked carefully without moving the mouth, she had an anxious expression and she guarded against having her face touched.

Examination revealed a slight dulling of sensation to pinprick in a spotty distribution over the mesial half of the mandibular division.

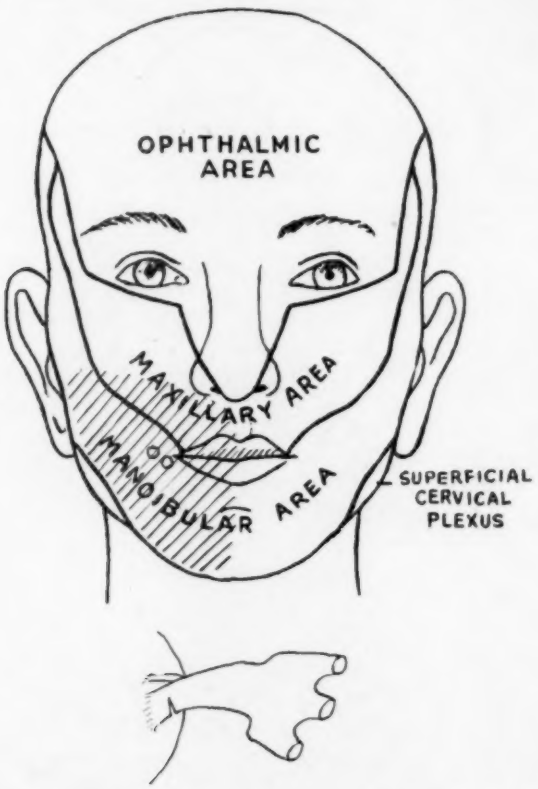

Fig. 8 (case 4).—The shaded area represents the region in which there were about a 25 per cent loss of sensation to pinprick and a hardly detectable loss of sensation to light touch, except in the areas marked by circles, where there seemed to be a complete numbness. Sensation in the tongue and buccal mucosa was about the same as in the region denoted by shadings. Herpes developed on the right side of the lips after the operation. Corneal sensation and the function of the motor fifth and seventh nerves were intact. No corneal ulcer was present. The patient denied feeling numbness to any degree in the face. The drawing at the bottom demonstrates the relative amount of the root sectioned.

The root of the fifth nerve on the right side was exposed by the cerebellar route, and about one third of the root was sectioned with the guillotine knife previously described.

Fig. 9 (case 4).—*A* shows the outline of the mild sensory changes shown in figure 8. *B* shows the scar of the operation. I have subsequently lessened the extent of this incision.

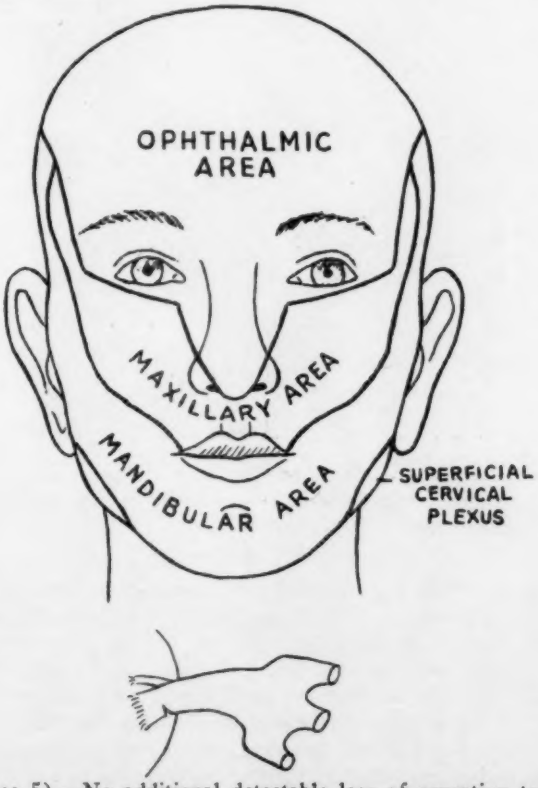

Fig. 10 (case 5).—No additional detectable loss of sensation to pinprick, light touch, pressure, temperature or two point discrimination was present in the face. No loss of sensation to pinprick or to light touch on tongue, lip, gums or buccal mucosa was noted. Herpes developed on the right side of the lips after the operation. Corneal sensation and motor function of the fifth and seventh nerves were intact. No corneal ulcer was present. The drawing at the bottom demonstrates the relative amount of root sectioned.

The patient recovered uneventfully, and repeated sensory examinations revealed no detectable loss in sensation on the tongue, in the buccal mucosa or on the face, except that which had been present before the operation. Heat, cold and pressure were also interpreted normally (fig. 10). The "tic" crises were abolished, and she did not complain of hyperesthesia in the right side of the face. Corneal sensation and the function of the motor fifth and seventh nerves were intact.

Unfortunately, when she was ready for discharge "butterfly" erysipelas developed over the face, with a severe reaction which became complicated by streptococcic meningitis, causing death. Permission for necropsy was denied.

CASE 6.—B. McC., a white man aged 67, was referred to me by Dr. R. C. Crumpton, of Webster City, Iowa, in May 1937.

Fig. 11 (case 6).—Photograph taken four days after the operation, illustrating a small incision which provides adequate exposure for the operation. The midsagittal plane is indicated.

This patient, in addition to having paralysis agitans, had suffered frequent attacks of tic douloureux for five years. The attacks were in the second and third branch distribution on the right. Eating, talking and stroking the upper lip on the right side were inciting stimuli. Several injections of alcohol had been attempted. There had also been an unsuccessful attempt to make an injection into the ganglion. An infection developed in the right temperomandibular joint, with cellulitis of the right side of the face, which was the site of two draining sinuses. The infection precluded further attempt at the injection of alcohol as well as operative attack by the subtemporal route. The attacks were so frequent and so difficult to bear that the patient was eager to have an operative section. Fortunately the tissues posteriorly were not infected, and a partial section of the sensory root was carried out by the cerebellar route. The operation was done

with the area under local anesthesia, and, strangely, as has been pointed out by Dandy, no sensation of pain was induced when the root was sectioned. The inferior two thirds of the root was sectioned with the guillotine knife without the slightest difficulty and with minimal retraction of the cerebellar hemisphere. A greater portion of the root was sectioned than was thought to be necessary, in the hope of diminishing the pain in the jaw from infection. The "tic" was abolished, and after the operation the patient felt no numbness in the face. The department of neurology reported that fully 75 per cent of sensation to touch and pain was preserved in the second and third branch distribution. The pulling of a whisker in this region was keenly felt, though not quite so sharply as in a comparable location on the opposite side.

This case illustrates not only the advantage but the occasional necessity of a cerebellar approach to the fifth cranial root. It is also illustrative of the fact that the section may be accomplished through a relatively small opening (fig. 11).

COMMENT

These representative and carefully studied cases demonstrate, in my opinion, that it probably makes no significant difference from a physiologic standpoint where the root is sectioned, provided comparable sections are made. So far the sections made by the subtemporal route have been far more extensive than those made by the cerebellar route. The subtemporal exposures were the earlier operations. Subsequently I became more courageous in deciding to cut less of the root. Even so, the results with the two exposures indicate a comparability. After developing the cerebellar technic, I have chosen to use it in preference to the subtemporal for technical reasons and I believe that with the guillotine knife the section can be better controlled.

However, there are contraindications for the cerebellar exposure, as Dandy has pointed out, for example, latent mastoid infection on the same side and deafness on the opposite side.

I hope to further these studies by sectioning less of the root by the subtemporal exposure.

In the last analysis, the neurosurgeon should be equipped and skilled to carry out both exposures, and thus lend the flexibility to his decision in the given case that these two excellent operations can provide.

A history of repeated injections of alcohol, particularly in the third branch, may become a contraindication to the subtemporal exposure.

If there exists the slightest doubt concerning the possibility of a tumor in the cerebellopontile angle, the cerebellar approach is the method of choice, and the presence of such a tumor in 5 per cent of Dandy's cases deserves consideration. Obviously a most careful examination of the patient with tic douloureux should be made before the operation with this in mind, and it appears that the presence of any significant organic lesion about the root would be made known by at least a diminishing of the sensitive corneal reflex on the homolateral side. The

patient with "tic" is so wary that the examiner probably often foregoes a careful examination, but for the ultimate good of the patient he should not do so.

INJECTION OF ALCOHOL

There was a time when the injection of alcohol deserved serious consideration as an alternative to section of the root. The most valid argument in its behalf was that it trained the patient to bear the numbness he must permanently endure should he consent to the operation.[18] The situation is now reversed, for the possibilities of partial section of the sensory root offer the patient a cure with no significant subjective sensory loss, while injection of alcohol produces a total sensory loss in branch distribution.

Injection of alcohol should, therefore, take its place among obsolete treatments for tic douloureux. It may occasionally find justified use for patients with operation phobia and for those for whom surgical treatment of any kind would be a decided risk.

Other compromises in the treatment of tic douloureux are seldom deserving of practical consideration at the present time.

SUMMARY

Tic douloureux is discussed from the standpoint of its possible cause and of the paradoxic phenomena that result from partial section of the root. Explanations for the latter are suggested.

It is believed that many of the discrepancies in the results obtained by different operators may be due to degrees of avulsion of the root when the hook or the hook knife is used, of which the operator may not be cognizant. I have designed a guillotine knife which I find useful in obviating this difficulty when making the section at the pons.

The subtemporal and the cerebellar approach are compared on the basis of my experience from surgical and physiologic standpoints. From purely surgical considerations, the cerebellar approach is preferred. From physiologic considerations, it is felt that it makes little difference where comparable sections are made in the root, so far as either the formation of corneal ulcers or the retention of sensation is concerned.

The surgeon should be skilled in making both approaches, and his choice should be determined by careful preoperative examination. The indications and contraindications for the approaches should be evaluated for the given case.

Partial section of the root can be done so as to eliminate the pain crises at least in the second and third branch distribution, and yet with

18. Horrax, G., and Poppen, J. L.: Experiences with Trigeminal Neuralgia and Treatment Employed in Four Hundred and Sixty-Eight Patients During the Past Ten Years, Surg., Gynec. & Obst. **61**:394-402 (Sept.) 1935.

losses of sensation in the face so small as to be entirely unnoticed by the patient—a result that leaves little to be desired in the perfection of this operation. The difference between partial and total section of the sensory root is of such great importance to the patient that every effort should be made to spare part of the root. It is my opinion that at least when the surgeon is dealing with pain in second and third branches a total section of the sensory root is an unnecessary mutilation and must be considered an obsolete operation.

CONCLUSIONS

1. A partial section of the sensory root of the fifth nerve can be done so as to abolish the pain crises and with such minimal sensory losses in the face as to cause no inconvenience to the patient.

2. Sensory losses obtained by progressive sectioning of the root are diffusely disposed and seem to be of a combined branch and segmental distribution, with evidence of extensive overlapping.

3. From a surgical standpoint, the cerebellar approach is preferred, but it requires experience in the cerebellar fossa. Greater care is necessary than in the subtemporal approach.

4. From a physiologic standpoint it probably makes no difference, so far as either the formation of corneal ulcers or the retention of sensation is concerned, at what point in the root comparable sections are made.

THROMBOSIS OF THE LEFT INTERNAL CAROTID ARTERY

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Obliteration of one or both carotid arteries has not infrequently been described as part of a widespread obstruction or total occlusion of large arteries given off from the aortic arch. Autochthonous thrombosis limited to the carotid arteries seems to be rare and may in fact never occur without some accompanying change in the cerebral vessels or in the aorta, particularly if considerable time has elapsed since the onset of the primary process. This paper reports 2 instances in which thrombosis was found in the left internal carotid artery and a segment of the thrombosed vessel was excised, in the first case for diagnostic study and in the second case for therapeutic purposes.

When occurring as part of a widespread thrombosis of the large vessels, involvement of the carotid arteries has often been attributed to arteriosclerosis. In some cases no other factors have been mentioned.[1] In many cases other processes, such as syphilis,[2] traction of

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1. (*a*) Yelloly, J.: Case of Preternatural Growth in the Lining Membrane Covering the Trunks of the Vessels Proceeding from the Arch of the Aorta, Med.-Chir. Tr., London **12**:565, 1822. (*b*) Fraenkel, E.: Ueber zwei durch total Verschluss der linken Carotis complicirte Aneurysmen des Aortenbogens [case 2], Virchows Arch. f. path. Anat. **79**:509, 1880. (*c*) Dejerine, J., and Huet, E.: Contribution à l'étude de l'aortite oblitérante, Rev. de méd., Paris **8**:201, 1888. (*d*) von Weismayr, A. R.: Ein Fall von Stenose der Carotis und Subclavia, Wien. klin. Wchnschr. **7**:906 and 925, 1894. (*e*) Högerstedt, A., and Nemser, M.: Ueber die krankhafte Verengerung und Verschliessung vom Aortenbogen ausgehender grosser Arterien [case 3], Ztschr. f. klin. Med. **91**: 130, 1897. (*f*) Erb, W.: Ein Fall von ausgedehnter Gehirnerweichung bei totaler Obliteration der Carotis communis sinistra, München. med. Wchnschr. **51**:946, 1904. (*g*) Raeder, J. G.: Ein Fall von symmetrischer Karotisaffektion mit praeseniler Katarakt und "Glaukom" sowie Gesichtsatrophie, Klin. Monatsbl. f. Augenh. **78**:63, 1927.

(Footnotes continued on next page)

a distorted aortic arch which narrows the mouths of the large arteries at their origin from the aorta,[3] embolism[4] or other inflammatory reactions,[5] have appeared alone or in association with arteriosclerosis. When the carotid system has been the primary site of the thrombosis in the absence of trauma or tumor, the etiologic factor often has been obscure. More or less circumscribed arteriosclerosis[6] or nonsyphilitic arteritis[7] also has been considered, and some reports have offered no suggestion as to the etiologic factor.[8] Carotid thrombosis associated with hyper-

2. (*a*) Parsons, C. W.: Case of Occlusion of the Arteries Arising from the Arch of the Aorta, with Aortic Degeneration and Aneurisms, Boston M. & S. J. **9**:400, 1872. (*b*) Lancereaux, E.: Des affections syphilitiques de l'appareil circulatoire [case, p. 59], Arch. gén. de méd. **2**:42, 1873. (*c*) Bernard, E.; Gilbert-Dreyfus, and Foulon, P.: Processus d'oblitération complète de l'artère sous-clavière et de la carotide primitive gauches et incomplète de l'artère sous-clavière droite chez un aortique, Bull. et mém. Soc. méd. d. hôp. de Paris **52**: 476, 1928. (*d*) Töppich, G.: Ueber nicht thrombotischen Verschluss der grossen Gefässostien des Aortenbogens, insbesondere des Ostiums der Carotis communis, Frankfurt. Ztschr. f. Path. **25**:236, 1921. (*e*) Aldrich, A. L.: Occlusion of the Left Common Cartoid Artery: Report of a Case, U. S. Nav. M. Bull. **22**:48, 1924.

3. Türk, W.: Arterieller Collateralkreislauf bei Verschluss der grossen Gefässe am Aortenbogen durch deformirende Aortitis, Wien. klin. Wchnschr. **14**:757, 1901.

4. Cohn, cited by Penzoldt.[6a] Fraenkel,[1b] case 1.

5. (*a*) Gull, W. W.: Thickening and Dilatation of the Arch of the Aorta with Occlusion of the Innominata and Left Carotid, and Atrophic Softening of the Brain, Guy's Hosp. Rep. **1**:12, 1855. (*b*) Savory, W. S.: Case of a Young Woman in Whom the Main Arteries of Both Upper Extremities and of the Left Side of the Neck Were Throughout Completely Obliterated, Med.-Chir. Tr., London **21**:205, 1856.

6. (*a*) Penzoldt, F.: Ueber Thrombose (autochthone oder embolische) der Carotis, Deutsches Arch. f. klin. Med. **28**:80, 1881. (*b*) Kussmaul, case 1, cited by Penzoldt.[6a] (*c*) Chiari: Ueber das Verhalten des Teilungswinkels der Carotis communis bei der Endarteriitis chronica deformans, Verhandl. d. deutsch. path. Gesellsch. **9**:326, 1906. (*d*) Harbitz, F.: Bilateral Carotid Arteritis [case 4], Arch. Path. **1**:499 (April) 1926. (*e*) Houwer, A. W. M.: Thrombose der Arteria carotis mit orbitalen Komplikationen, Arch. f. Augenh. **99**:240, 1928. (*f*) Wüllenweber, G.: Fortdauer des Lebens bei doppelseitigem vollständigem Verschluss der Aa. carotides internae, Deutsche Ztschr. f. Nervenh. **105**:283, 1928.

7. Harbitz,[6d] case 1.

8. (*a*) Elschnig, A.: Ueber den Einfluss des Verschlusses der Arteria ophthalmica und der Carotis auf das Sehorgan, Arch. f. Ophth. **39**:151, 1893. (*b*) Agatston, S. A.: Thrombosis of the Carotid and Middle Cerebral Arteries with Bilateral Hemorrhagic Optic Neuritis, Arch. Neurol. & Psychiat. **24**:1245 (Dec.) 1930. (*c*) Hyland, H. H.: Thrombosis of Intracranial Arteries [case 3], ibid. **30**:342 (Aug.) 1933.

tension has occasionally developed in the presence of abnormal reactions of the carotid sinuses, but the mechanism of this process has not yet been thoroughly worked out.[9]

REPORT OF CASES

CASE 1.—A Russian aged 47 years was admitted to the Peiping Union Medical College Hospital on Dec. 27, 1935. Although he had suffered considerable hardship and poverty during his life, he repeatedly denied trauma or infections other than "colds," "stomach trouble" at the time of the World War and gonorrhea twenty years previously. He denied having had syphilis. Since about 1930 there had been increasing difficulty with vision. In the early spring of 1935, while working in timber concessions in Manchuria, he began to have short periods of numbness in the right arm and leg, for which he was admitted to the hospital of the Chinese Eastern Railway. On discharge he found work as a switch operator on the Chinese Eastern Railway at Harbin at the time the Japanese took over the administration of the railway. A friend stated that even then the patient was nervous, talkative, absent-minded and forgetful, concentrated on himself and worried about his physical condition. In the summer of 1935 he complained of being tired by the long hours of work and headaches, and his poor eyesight prevented him from seeing the railroad signals clearly from a distance. About a month after starting his work he threw a switch the wrong way and caused the wreck of a locomotive and seven empty freight cars. On one occasion he fell down while at work, with temporary "paralysis" of the right side and inability to talk. He was readmitted to the hospital of the Chinese Eastern Railway for a short time, after which he returned to the same work. By September 1935 he was "nervous all the time" and was subject to almost constant headache and to occasional attacks of weakness of the right side. His correspondence with his friends became disorganized, and on their advice he finally left Harbin, coming to Peiping on Dec. 9, 1935. At that time he seemed constantly worried, had much difficulty in expressing himself, was slow to understand what was said to him and appeared emotional, with rather frequent exhibitions of tears.

On admission to the Peiping Union Medical College Hospital his complaints were of headache, cold sensations in the right arm, the feeling that the right arm had dropped off, attacks of weakness in the right arm and leg, with accompanying inability to speak, impairment of memory, inability to find the words he wanted, noises in the head, poor vision, difficulty in sleeping and general nervousness.

Physical examination showed vision of 6/9 in each eye and concentric constriction of the visual fields but no consistent disturbance of motility, of sensation to objective tests or of the reflexes. There was gross difficulty in word finding, the patient being unable to express himself consecutively for more than a sentence or two and often being unable to produce a single word promptly in answer to a simple question about himself. Naming objects and colors, calculation, memory for sequence of remote and recent events, and right-left orientation of the body were all

9. (*a*) Hiller, F.: Die Zirkulationsstörungen des Rückenmarks und Gehirns, in Bumke, O., and Foerster, O.: Handbuch der Neurologie, Berlin, Julius Springer, 1936, vol. 2, p. 409. (*b*) Marinesco, G., and Kreindler, A.: Oblitération progressive et complète des deux carotides primitives; Accès épileptiques, considérations sur le rôle des sinus carotidiens dans la pathogénie de l'accès épileptique, Presse méd. **44**:833, 1936.

markedly impaired. The results of additional psychologic tests are given in table 1. The Wassermann reaction of the blood was negative; the blood pressure was 100 systolic and 62 diastolic. On Feb. 12, 1936, one of us (H. H. L.) exposed the left carotid arteries, with the intention of injecting colloidal thorium dioxide for arterial encephalography. A needle was inserted into the internal carotid artery just distal to its point of origin. As the needle passed into the vessel the resistance of a solid structure was encountered, and it was impossible to withdraw blood. Repeated punctures were made in various directions with the same result. The

TABLE 1.—*Psychologic Tests Before and After Operation (Case 1)*

Tests	Before Operation		After Operation	
	Results	Date	Results	Date
Retention of digits (forward)	4 digits; mental age, 4 yr.	Jan. 15	5 digits; mental age, 7 yr.	Feb. 20
Retention of digits (backward)	Failed	Jan. 15	Failed	Feb. 20
Naming of colors	None	Jan. 15	Named correctly 3 in 5	Feb. 20
Immediate visual memory	Poor	Jan. 17	Improved (?)	Feb. 20
Diagonal form board	Time, 3′ 18″; errors, 37	Jan. 17	Time, 1′ 42″; errors, 27	Feb. 20
Five figure form board	Errors, 26; time, 3′ 30″	Jan. 20	Errors, 30; time, 2′ 39″	Feb. 20
Casuist form board	Errors, 17; time, 4′ 20″	Jan. 20	Errors, 15; time, 1′ 54″	Feb. 20
Two figure form board	Failed	Jan. 18	Failed	Feb. 20
Cube knob	Mental age, 6 yr.	Jan. 15	Mental age, 6 yr.	Feb. 25
Repeating of syllables	Mental age, 3 yr.	Jan. 15	Mental age, 5 yr.	Feb. 25
Mental arithmetic test	Mental age, 6.3 yr.	Jan. 23	Mental age, 5.3 yr.	Feb. 21
Graded direction test	12% (mark)	Jan. 22	20%	Feb. 21
Maze test	Mental age, 13 yr. 6 mo.	Jan. 13	Mental age, 12 yr.	Feb. 27
Direction test	Mental age, 5.7 yr.	Jan. 22	Mental age, 6.2 yr.	Feb. 25
Immediate logical memory	Remembered 1/18 of material	Jan. 18	Remembered 7/18 of material	Feb. 27
Drawing of human being	With double profile	Jan. 23	Much better; without double profile	Feb. 22
Clock tests				
Direct imitation	50%	Jan. 21	55%	Feb. 26
Clock set to oral commands	0%	Jan. 21	0%	Feb. 26
Telling the time	20%	Jan. 21	30%	Feb. 26
Written commands				
Reading commands	80%	Jan. 24	100%	Feb. 27
Setting clock	0%	Jan. 24	20%	Feb. 27
Coin bowl test				
Oral commands	17%	Jan. 23	92%	Feb. 26
Written commands in full (not read aloud)	25%	Jan. 23	50%	Feb. 26
Written commands in full (read aloud)				
Reading commands	75%	Jan. 23	42%	Feb. 26
Following out commands	58%	Jan. 23	42%	Feb. 26
Written commands in abbreviation	83%	Jan. 23	67%	Feb. 28

needle was then inserted into the lumen of the common carotid artery proximal to the point of bifurcation, and with the external carotid artery occluded by digital pressure, 10 cc. of thorium dioxide was injected. A roentgenogram which was taken as the injection was completed showed that none of the contrast medium had entered the internal carotid artery. Accordingly a small segment of the latter vessel was excised between ligatures of doubled medium-sized silk. The lumen of the artery was found to be filled completely with grayish material which on microscopic examination proved to be an organized thrombus.

On February 22 the patient said he felt much better and could "speak without stuttering." There was less numbness in the right arm, less noise was heard in

the head and sleeping was improved. He said, "Everything is much better." On February 23, 24 and 26 there was some headache, and the patient said he felt "nervous," but on February 27 he was free from headache, and on the following day he announced that he felt "physically well." Psychologic tests were repeated, and they confirmed a definite improvement in mental functions, as shown in table 1. The patient grew restless in the hospital and insisted on leaving, so he was discharged on March 2. He soon afterward went back to Harbin, and further word from him has not been obtainable.

Case 2.—A Chinese student of mathematics aged 27 years was admitted to the Peiping Union Medical College Hospital on April 2, 1937. Thirteen months previously, while talking to friends at school, he suddenly became unable to speak. He started at once to walk home and fell down on the way without losing consciousness. He was taken by rickshaw to his residence in the city and the next day proceeded by rickshaw to his family's home in the country. He felt drowsy

Table 2.—*Blood Pressure Before and After Operation (Case 2)*

Date	Blood Pressure, Mm. Hg, Left Arm	Date	Blood Pressure, Mm. Hg, Left Arm	Date	Blood Pressure, Mm. Hg, Left Arm
April 2	184/140 (200/142 right arm)	May 10	172/134	May 27	138/ 90
			148/128	28	124/ 90
4	142/104	11	184/138	29	130/100
5	182/142		172/130	30	126/ 90
7	152/111	12	178/138	June 2	128/ 90
11	154/118	13	188/138	3	132/ 96
12	152/104	14	170/138		124/ 90
17	164/122	15	168/128	4	120/ 88
21	146/110	16	160/120	5	124/ 88
24	148/ 98	17	160/120	6	126/ 88
25	140/ 96	18	152/110	7	124/ 88
26	156/104	19	150/100	8	134/ 84
May 1	150/100	20	150/110	9	120/ 74
2	140/100	21	152/102	11	130/ 90
3	154/100	22	130/ 90	14	130/ 92
7*	162/114	23	130/ 90	18	124/ 82
8	150/118	24	136/ 90	19	122/ 80
	170/130	25	140/100	20	118/ 80
9	178/142	26	138/ 94		
	190/136				

* Operation.

and somewhat "confused," but he knew where he was and with whom he was. Beginning on the second day paralysis and numbness of the right side gradually developed. He was unable to read Chinese characters, and for three months could make sounds but could not enunciate clearly. He then began to learn little by little to say some things intelligibly. Soon afterward he started to walk. He had to be fed for six months. With considerable effort he learned to read some characters and taught himself to write them with his left hand, but for six months his condition had been physically and mentally almost stationary.

On admission to the hospital he was found to have hypertension (table 2) without cardiac enlargement. The neurologic examination showed his vision to be: left, 6/30; right, 6/20. There were nasal hemianopia of the left eye and contraction of a sector of the upper temporal field of the right eye, retinitis pigmentosa and hypertension of the retinal vessels. There was hemiplegia of the right side (the arm chiefly) of distal type, with corresponding signs of involvement of the pyramidal tracts and reduction of sensation of all sorts, including discrimination of form, weight, texture and Chinese characters traced on the skin, on the right side. There also was pronounced motor and receptive aphasia, calculation, reading and writing being especially affected. Details of

the psychologic tests before and after operation are given in table 3. Palpation of the common carotid arteries showed less amplitude of pulsation on the left side. Pressure over the right carotid sinus gave no indication of hypersensitivity of that structure. Pressure over the left sinus was consistently followed by deep and irregular respiration and by dizziness, but there was no change in pulse rate or blood pressure. Digitalization increased the effect of pressure over the left carotid sinus. The Wassermann reaction was negative for both blood and cerebrospinal fluid. On May 7 one of us (S. T. K.) exposed the carotid arteries on the left side and denervated the left carotid sinus. Thorium dioxide was then

TABLE 3.—*Psychologic Tests Before and After Operation (Case 2)*

1. Motor Tests Before and After Operation

Motor tests	Before Operation	After Operation
Speed of cutting S	24 min. 10 sec.	13 min. 10 sec.
Errors of cutting S	118.8 mg.	51.2 mg.
Speed of cutting star	38 min. 17 sec.	28 min. 32 sec.
Errors of cutting star	262.4 mg.	158.6 mg.
Tapping	174 in 30 sec.	178 in 30 sec.
Strength of right hand	1 Kg.	4 Kg.
Strength of left hand	32 Kg.	41.8 Kg.
Handwriting	.....	Steadier and better in strokes and fewer reversed words
Speed of handwriting	3½ words in 40 sec.	13 words in 40 sec.
Tactile recognition of objects		
Right hand	Number of correct answers, 17%; average speed, 8 sec.	Number of correct answers, 8%; average speed, 6.3 sec.
Left hand	Number of correct answers, 79%; average speed, 10.3 sec.	Number of correct answers, 71%; average speed, 9.1 sec.

2. Mental Tests Before and After Operation

Mental tests		
Intelligence tests	I. Q., 48	I. Q., 54
Interpretation of pictures	44%	33%
Solution of problem situations	75%	60%
Form analysis	67%	84%
Repetition of digits	30%	30%
Repeating digits backward	14%	14%
Immediate reproduction of cube tapping	33%	66%
Immediate reproduction of a paragraph	27%	46%
Reorganization of dissected sentences	0%	0%
Clock tests	Errors, 8; average speed, 71 sec.	Errors, 8; average speed, 54.7 sec.
Immediate visual memory	50% correct	50% correct
Understanding of separate abstract words	57% correct	50% correct
Reading of different words	56%	76%
Understanding of the reading	15.8%	18%
Drawing	.....	More details but same as before in general
Chinese puzzles	13%	66%

injected into the left common carotid artery, and a roentgenogram was taken near the end of the injection. It showed filling of the external carotid artery and its branches but complete lack of visualization of the internal carotid artery. A small needle was then introduced into this vessel. It met uniform resistance, and blood could not be withdrawn, although the needle was finally pushed deliberately all the way through the artery. Complete occlusion being demonstrated, a segment of the artery was excised, and the lumen was shown to be completely filled with an organized thrombus, as in case 1. After operation there was not much change in the condition of the patient. The blood pressure rose and then fell below the initial pressure, as shown in table 2. Resistance of the right arm

to passive movement on daily manipulation became somewhat less, and the patient became able to move the fingers of his right hand in isolated flexion and extension without overflow of movement to the whole arm, a procedure which he had not been able to carry out before the operation. He showed some subjective improvement in speech, but the psychologic tests demonstrated only slight improvement, if any, in mental function (table 3).

COMMENT

The symptoms of occlusion of the carotid artery have been discussed in an extensive literature on ligature of the carotid artery and will not be reviewed here. Information gained by the mental tests in the 2 cases reported in this paper, however, deserves comment. The results of a number of tests of general intelligence showed a rather uniform reduction of performance. This does not necessarily prove diffuse damage to the brain. The majority of tests commonly used to measure general intelligence are based on the use of words, often with special reference to word finding, the use of figures and the appreciation of certain visual relations. These functions have some local representation in the left parieto-occipital region of the brain in right-handed persons. With some appreciation of this emphasis in the structure of tests of intelligence, Kleist [10] stated that intellectual disturbances increase in frequency and severity the closer the site of the wound is to the occipital lobes and to the region of sensory speech. Mental tests have considerable value, but their interpretation must be made from a broad point of view. Case 1 illustrates the difficulty in interpretation. The only consistent symptoms were concentric constriction of the visual fields and a reduction of mental performance, which included defective word finding, calculation, right-left orientation of the body and memory. This suggested to one of us (R. S. L.) the original diagnosis of a vascular lesion in the left parieto-occipital region. It was the expectation of demonstrating such a condition that led to arterial encephalography, which provided the unexpected demonstration of thrombosis of the left internal carotid artery. But even here, one is not justified in discarding all localizing value of these mental tests in view of the frequent occurrence of embolus or thrombosis or other vascular pathologic conditions in the brains of patients with carotid thrombosis examined at autopsy.[11] Terminal branches of the middle cerebral artery appear to be most affected after occlusion of the carotid artery, and so the mental functions having some representation in the left parieto-occipital distribution

10. Kleist, K.: Gehirn Pathologie vornehmlich auf Grund der Kriegserfahrungen, Leipzig, Johann Ambrosius Barth, 1934, p. 550.

11. Fraenkel.[1b] Erb.[1f] Lancereaux.[2b] Gull.[5a] Penzoldt.[6a] Chiari.[6c] Harbitz.[6d] Houwer.[6e] Wüllenweber.[6f] Elschnig.[8a] Agatston.[8b] Hyland.[8c] Hiller.[9a] Marinesco and Kreindler.[9b]

of these terminal arteries might be expected to be affected. A still wider point of view would take into account the importance of the left parieto-occipital region during evolution. The parietal lobes have undergone the greatest increase in volume, more than that of the much vaunted frontal lobes.[12] The ability to construct and use to an increasing degree of complexity such symbols as words, graphic signs and figures in calculation has a definite relation to the left parieto-occipital area. Since this aspect of intelligence is a high point in evolution, it might be one of the functions to be first and most markedly affected by any generalized disturbance such as toxemia or interference with the nutrition of the whole brain.

To summarize, in the 2 cases reported in this paper, mental tests showed a reduction of general intelligence, but this must be interpreted with caution since it may represent a diffuse change in the brain, perhaps nutritional, or it may indicate focal secondary damage in the most salient part of the vascular tree which springs from the left internal carotid artery. The frequency of secondary vascular lesions in the parietal lobes in cases of carotid occlusion makes the latter possibility seem likely. For the practical purposes of this paper the mental tests are not included with reference to localization in the brain but serve merely to indicate the comparison of the conditions before and after operation. From this standpoint the results seem important enough to be recorded in some detail in tables 1 and 3.

The response to pressure on the carotid sinuses unfortunately was not noted in case 1. In case 2, pressure on the right carotid sinus had no effect, while pressure on the left sinus uniformly caused deep and somewhat irregular breathing and dizziness but did not produce any significant change in pulse rate or blood pressure. These symptoms were intensified by digitalization. This was regarded as a somewhat abnormally sensitive sinus reaction of "cerebral type" [13] and, in conjunction with a palpably reduced amplitude of pulsation in the left common carotid artery and fluctuation of the blood pressure between 142 systolic and 104 diastolic and 200 systolic and 142 diastolic, led to the recommendation of surgical exploration of the left carotid region. It was predicted that denervation of the left carotid sinus would be followed by a rise of blood pressure which would later fall to a level

12. Weidenreich, F.: Observations on the Form and Proportions of the Endocranial Casts of Sinanthropus Pekinensis, Other Hominids and the Great Apes: A Comparative Study of Brain Size, Palaeontologia Sinica, s. D. (no. 4), 1926, vol. 7.

13. Weiss, S.; Capps, R. B.; Ferris, E. B., and Munro, D.: Syncope and Convulsions Due to a Hyperactive Carotid Sinus Reflex, Arch. Int. Med. **58**:407 (Sept.) 1936.

controlled by the presumably normal right sinus together with the other cardiovascular regulatory mechanisms. After denervation of the sinus and excision of a segment of the thrombosed carotid artery, the blood pressure behaved as expected (table 2). The exact role of the sinus in this case cannot be known, but it seems clear that it played an important part in the hypertension. An attractive hypothesis would be that the abnormal sinus reaction on the left side exposed the brain to bouts of high pressure under circumstances in which the blood was forced in freely through the vertebral arteries and the right carotid artery but not through the left carotid artery; this unbalanced increase of pressure seemed to intensify the difficulty of maintaining adequate blood flow through the smaller branches of the left middle cerebral artery and so hastened or actually brought about destruction of ganglion cells in this area of anoxemia. A direct reflex action on the cerebral vessels by the carotid sinus has been proposed [14] and, if existent, would have a good setting for exhibiting its influence in this case. Another type of effect of the carotid arteries on cerebral circulation may be due to sympathetic fibers carried up the carotid arteries to the cerebral vessels. In the words of Leriche,[15] an "obliterated artery ceases to be an artery and becomes a diseased sympathetic nerve."

The etiologic factor in carotid thrombosis is not known. In neither case reported here was there positive evidence of syphilis. In case 1 there was some bulging of the aorta to the right, with a markedly wide arch on fluoroscopy, but no other sign of arteriosclerosis or of hypertension was presented. In case 2 there was definite and variable hypertension, but its etiologic relation to the carotid sinuses, on the one hand, and to the carotid thrombosis, on the other, is in no way clear to us. It may be significant that in both cases there was an increase of fibrous tissue around the carotid arteries. In case 1 the tissues in the neighborhood were more difficult to separate than usual, normal cleavage planes being partly obliterated as though an old inflammatory process had been present. However, a definite source of a local inflammatory process in the neck could not be found on physical examination or on repeated questioning of the patient. In case 2 there was an unusual amount of fibrous tissue outside as well as inside the carotid sheath. The reports of the pathologic examination of the excised arterial seg-

14. Ask-Upmark, E.: The Carotid Sinus and the Cerebral Circulation, Copenhagen, Levin & Munksgaard, 1935, pp. 23-37 and 262-266. Gollwitzer-Meier, K., and Schulte, H.: Das Verhalten der Hirndurchblutung bei Reizung der Sinusnerven, Arch. f. exper. Path. u. Pharmakol. **165**:685, 1932. Bouckaert, J. J., and Jourdan, F.: Sinus carotidiens et circulation cérébrale, Compt. rend. Soc. de biol. **121**:1354, 1936.

15. Leriche, R.: Arterectomy in the Treatment of Localized Arterial Obliterations, Am. J. Surg. **14**:55, 1931.

ments offer no explanation of the cause for the thrombosis, but there is comment on the absence of any significant arteriosclerotic change in the walls of the arteries.

In case 1 no treatment was intended; excision of a segment of the artery was carried out for diagnostic purposes. It happened that the patient felt better after the operation; mental tests originally given for a different purpose were repeated, and they confirmed the improvement in mental performance. In case 2 the treatment was deliberately twofold: denervation of an abnormally reacting carotid sinus and excision of a thrombosed carotid artery.

The literature on denervation of the carotid sinus gives few clinical data relating to prophylaxis against pathologic conditions of the cerebral blood vessels. The procedure sometimes has been aimed at the production in persons with low pressure of a higher pressure, which in fact would be only temporary.[16] It seems to us that its main value might lie in the prevention of cerebral ischemia by relieving irregular hypertension due to a hypersensitive sinus. Theoretically this is possible, and the course of the blood pressure in case 2, so far as it goes, suggests that the denervation of the sinus made the brain safer from the effects of the previously existent irregularly high blood pressure and perhaps also from reflex effects on the cerebral vessels from the region of the carotid sinus and carotid artery.

Excision of a segment of the thrombosed carotid artery was carried out in accordance with the principles described by Leriche.[16] This procedure could influence the cerebral circulation, especially in the distribution of the left middle cerebral artery, and thereby improve the corresponding mental functions. It was not technically easy to remove the entire obliterated internal carotid artery, and for this reason it was not done, in spite of Leriche's recommendation that the entire occluded artery be resected. But at least the removal of a thrombosed segment interrupted the continuity of sympathetic impulses in the walls of the artery. Definite improvement followed this procedure in case 1. This cannot be attributed to psychologic influence alone. The pathologic observations were explained to the patient soon after the operation. He did not expect a cure from the operation, and he was also growing restless in the hospital even before the postoperative testing was completed. The improvement must be regarded as an increase in actual mental ability to perform the tasks and was obviously not due to a better attitude or more concentrated effort in doing the tests. The factor of learning cannot play a significant part in view of the large battery used in the testing and the fact that each task was done only twice,

16. Leriche, R.; Fontaine, R., and Froehlich, F.: L'énervation sinu-carotidienne est-elle permise au point de vue physiologique? Presse méd. **43**:1217, 1935.

once before and once after the operation. It should be noted that in case 1 relatively little neurologic evidence of irreversible damage to the brain was presented even before the operation. In case 2 the results of operative therapy were not so striking. There were a little increase in facility of individual movements with the right hand and fingers, some change in subjective sensation on the right (feeling of warmth, etc.), subjective improvement in word finding and writing, and better speed and accuracy in tests of motility, including handwriting; but from other mental tests there was only slight objective evidence of any significant improvement in mental ability. In contrast to case 1, in case 2 there was a history of a stationary condition for several months before the operation, during which the motor, sensory and mental findings implied considerable irreversible damage to the brain.

Finally, the experience gained in these 2 cases suggests a therapeutic formula. For a patient with symptoms of a cerebral vascular disturbance in the parietal region, with a unilateral reduction of pulsation in the common carotid artery and with a unilateral abnormal response of the carotid sinus on the same side, especially in the presence of hypertension, surgical exploration of the extracranial carotid system seems justified. In such cases denervation of the sinus may have prophylactic value against further damage to the cerebral blood vessels. Moreover, at the time of the exploration the carotid arteries can be examined, and if thrombosis is found, excision of the thrombosed artery may be carried out. The degree to which this procedure may be therapeutically effective will be limited by the extent of irreversible damage to the brain cells which has already taken place before the operation.

SUMMARY

Two cases of thrombosis of the left internal carotid artery of undetermined etiologic origin are reported. The first patient had relatively little evidence of irreversible damage to the brain and after a segment of the thrombosed artery was excised showed definite improvement in subjective feelings and in the performance of mental tests. The second had hypertension and signs of considerable damage to the brain. After denervation of the left carotid sinus and excision of a segment of the thrombosed artery, the blood pressure rose and then fell to a rather constant normal level. There were definite improvement in subjective feelings and in some motor abilities but only slightly better performance of other mental tests.

The syndrome consisting of signs of vascular disturbance in the distribution of the middle cerebral artery, with unilateral reduction in amplitude of pulsation in the common carotid artery and unilateral abnormal reactions of the carotid sinus on the same side, especially if

hypertension is present, is proposed as adequate indication for surgical exploration of the extracranial carotid system. In such cases denervation of the carotid sinus may have prophylactic value against later ischemic changes in the brain by protecting it from excessive alterations of blood pressure due to the hypersensitive sinus and perhaps by interrupting an abnormal chain of reflexes between the carotid artery and the cerebral vascular system. At operation, if thrombosis of the carotid artery is found, excision of a thrombosed segment may be definitely therapeutic but may be limited by the degree of the previous damage to the brain.

PILONIDAL SINUS

SCLEROSING METHOD OF TREATMENT

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The pilonidal sinus is an extremely interesting and troublesome lesion and has been the subject of much speculation and study. It is more common than physicians are wont to believe and is often unrecognized or confused with other lesions. It is found posterior to the sacrum and the sacrococcygeal region and is variously described as sacrococcygeal cyst, dermoid, coccygeal fistula, a sacral sinus or postanal dermoid. This confusion is characteristic not only of the nomenclature but also of the etiology, pathology and treatment.

The purpose of this paper is twofold: first, to review briefly the subject of pilonidal sinus, because this information may be essential in determining the operative method to be employed; second, to report and discuss four years of experience with the use of a sclerosing solution in the treatment of this disease.

ETIOLOGY

There are two prevalent theories of the cause of pilonidal sinus. The first, advanced by Tourneux and Herrmann [1] in 1887, is that the condition is due to the persistence of coccygeal vestiges of the neural canal. Mallory [2] in 1892, Oehlecker [3] in 1926, Gage [4] in 1935 and others made worthy contributions advocating this embryologic theory of the formation of the pilonidal sinus. The second theory, postulated by Lannelongue [5] from 1882 to 1886, is in effect that these sinuses are due to faulty median skin agglutination of the sacrococcygeal region. Lannelongue was supported in this contention by Aschoff [6] in 1895, Stone [7]

From the proctologic service of the Elgin State Hospital.

1. Tourneux, F., and Herrmann, G.: J. de l'anat. et physiol. **23**:498, 1887.
2. Mallory, F. B.: Am. J. M. Sc. **103**:263, 1892.
3. Oehlecker, F.: Deutsche Ztschr. f. Chir. **197**:262, 1926.
4. Gage, M.: Pilonidal Sinus: Explanation of Its Embryologic Development, Arch. Surg. **31**:175 (Aug.) 1935.
5. Lannelongue: Bull. méd., Paris **3**:371, 1889; Bull et mém. Soc. de chir. de Paris **7**:185, 1882; **12**:460, 1886.
6. Aschoff, L.: Cysten, in Lubarsch, O., and Ostertag, R.: Ergebnisse der allgemeinen Pathologie, Wiesbaden, J. F. Bergmann, 1895, p. 456.
7. Stone, H. B.: Ann. Surg. **79**:410, 1924; **94**:317, 1931.

in 1924, Breidenbach and Wilson [8] and also by Fox [9] in 1935, and many others. It is imperative, therefore, to bear in mind that, assuming that the earlier theory of Tourneux and Herrmann is correct, a communication may exist directly between a pilonidal sinus and the neural canal, or it may exist indirectly through an anterior tumor. In such an instance the method of treatment here to be advocated is definitely contradicted.

PATHOLOGIC PICTURE

The pathologic condition consists of an acute or chronic inflammation of a localized area in the sacrococcygeal region. A single, skin-lined round or oval orifice is seen in the midline about 1½ to 2 inches (3.7 to 5 cm.) from the tip of the coccyx. This orifice, from which a tuft of fine silky hair may protrude (this was seen in only 2 cases in our series), leads into a skin-lined main tract (fig. 1 *A*). The tract varies in length from 3 to 7 cm. It runs upward and occasionally downward for a very short distance unless it is associated with a fistula in ano like that in the case reported by Warman.[10] One of our patients presented this rarity. A bulbous pouch (fig. 1 *B*) is frequently found at either end of the tract; or there may be a number of sacculations, existing as separate cavities, which may communicate with each other or with the main tract by means of lateral tracts; or some of these may drain through external orifices in the skin. Subsidiary orifices caused by extension of the infective process may be found in the midline or to one or the other side of it. These vary in size, are irregular and discolored and are usually filled with granulation tissue and purulent material.

The dispute as to the histologic picture is interesting. Breidenbach and Wilson [8] maintained that the cutaneous appendages described by others could not be found. They detected areas of acute or chronic inflammation with numerous foreign body giant cells, some hair without the hair follicles, small islands of squamous cells, either free or doubtfully attached to the lining of the cyst, and squamous epithelium at the entrance of the sinuses. Oehlecker [3] made careful microscopic studies, including serial sections, but found no epithelial structures. Neither was nerve tissue seen by these observers, although Gage,[4] in his study of the subject, described glial tissue beneath the epithelial lining in lesions which extended as far as the dura. However, the presence of cutaneous appendages, such as hair follicles, sebaceous glands and sweat glands, described by Gussenbauer [11] in 1892 and by Crone [12] in 1917 as

8. Breidenbach, L., and Wilson, H. L.: Ann. Surg. **102**:455, 1935.
9. Fox, S. L.: Surg., Gynec. & Obst. **60**:137, 1935.
10. Warman, W. M.: West Virginia M. J. **32**:80, 1936.
11. Gussenbauer, C.: Prag. med. Wchnschr. **18**:441, 1893.
12. Crone, E.: München. med. Wchnschr. **64**:521, 1917.

appearing in the cystic tissue of such lesions, was confirmed recently by Stone,[7] Fox,[9] Rogers and Hall [13] and others.

Since no radical excisions were performed in the cases in our series, we secured only small sections of tissue for study. Figure 2 shows a section taken from a typical sinus ending in a pouch. A well developed hair follicle surrounded by connective tissue, round cell infiltration and fat cells, was the only one discovered deep under the epithelial surface.

Fig. 1.—*A*, typical appearance of a chronic pilonidal sinus. The sinus is situated, as usual, in the midline of the sacrococcygeal region. Mercurochrome has been applied for visualization of the multiple orifices. The distal orifice is skin lined and is the congenital opening into the sinus. The one immediately above and another at the proximal end and to the left are secondary to a spontaneous rupture of abscesses, the latter being considerably larger, gaping, elevated and inflamed. Two pouches were found communicating with the main tract, the lower one draining through the small openings and the upper one draining indirectly through the large ragged opening. This proximal pouch was completely filled with fine hair packed tightly into a ball. *B*, roentgenogram of a pilonidal sinus after the injection of iodized poppyseed oil. The narrow tract terminates in a pouch at the proximal end.

13. Rogers, H., and Hall, M. G.: Pilonidal Sinus: Surgical Treatment and Pathologic Structure, Arch. Surg. **31**:742 (Nov.) 1935.

The sinus from which this section of tissue was taken was injected with iodized poppyseed oil and a roentgenogram was taken (fig. 1 *B*), as suggested by Brams.[14]

DIAGNOSIS

Despite the fact that the lesion characteristic of this disease is typical, the condition is frequently misdiagnosed. A thorough proctologic examination, including sigmoidoscopic, anoscopic and roentgenologic study, should be made in every case before any treatment is decided on or attempted. In the early stage, when no infection is present, one may find only a dimpling of the skin or a small skin-lined orifice leading into a tract directed upward for a variable distance. When the condition is acute, there are tenderness, swelling and redness over the lower part of

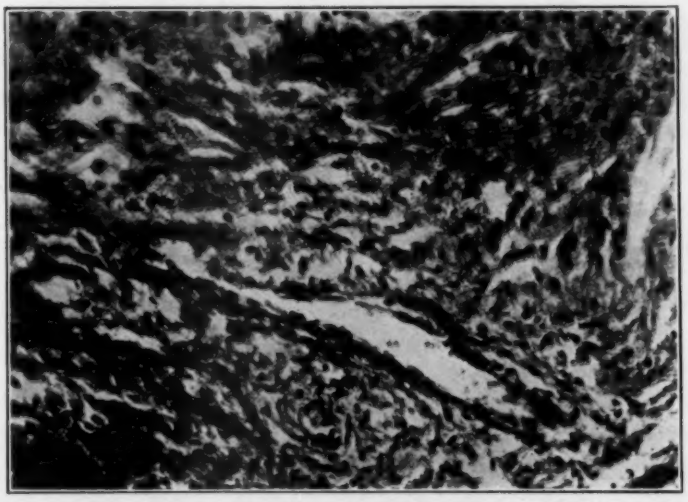

Fig. 2.—Section of tissue removed from the cystic portion of a sinus, showing a well developed hair follicle surrounded by connective tissue, round cell infiltration and fat cells.

the sacrum in the midline between the buttocks about 2 inches (5 cm.) posterior to the anal verge; or the process may extend down on either side of the buttocks.

Pilonidal sinus must not be confused with fistula in ano, ischiorectal abscess, simple furuncle, sebaceous cyst, tuberculosis, osteomyelitis, lipoma, inflammation of the congenital tumors, anthrax or actinomycosis.

INCIDENCE

The pilonidal sinus is common and occurs in early adult life. In conformity with the experience of others, the ages of the patients in our series of cases ranged from 18 to 51 years (see table). Men predom-

14. Brams, J.: Radiology **8**:248, 1927.

inated over women in a ratio of 8 to 3. There were no Negro patients. The majority of the patients were of the obese hirsute type. One patient was tuberculous, 1 was paretic and 1 was convalescent after encephalitis.

SYMPTOMS

The early dimple stage is usually symptomless. The acute stage is characterized by swelling and by severe pain over the sacrococcygeal region and over the lower part of the back. The pain radiates down one or both thighs or to the rectum, is rather constant, varies in intensity and is aggravated by sitting, by walking and sometimes by defecating. There may be fever, chills and malaise. In the chronic stage the chief complaint is a dull aching pain in the involved region on walking or sitting, a discharge of pus which often causes itching, an odor and the presence of hair in the orifice leading into the tract.

PROGNOSIS

Recurrence appears to be the bane of almost every radical procedure employed in the treatment of this disease. The condition frequently

Distribution of Patients According to Age and Sex

Age	18	21	23	24	28	34	39	41	46	51
Number of patients	2	1	1	1	1	1	1	1	1	1
Sex	F	F	M	M	M	M	M	M	M	M

demands a second operation, and occasionally, repeated surgical intervention is necessary. A perusal of some of the figures is interesting. Weinstein,[15] Ferguson,[16] Thomason [17] and Rogers and Hall (third series [13]) reported no recurrences; Colp,[18] Ottenheimer,[19] Smiley,[20] Lynch [21] and others did not mention the exact percentage of recurrences in their series of cases, alluding only to their frequency. However, Worter [22] reported 15 per cent, Owen [23] 5 per cent, Breidenbach and Wilson [8] an average of 35 per cent, Glenn [24] 17 per cent, Cattell and Stoller [25] about 22.5 per cent and Stone [7] 5 to 8 per cent when the opera-

15. Weinstein, M.: Ann. Surg. **97**:80, 1933.
16. Ferguson, L. K.: Ann. Surg. **101**:469, 1935.
17. Thomason, T. H.: Ann. Surg. **100**:585, 1934.
18. Colp, R.: S. Clin. North America **9**:695, 1929.
19. Ottenheimer, E. J.: Am. J. Surg. **21**:120, 1933.
20. Smiley, K. E.: Am. J. Surg. **27**:298, 1935.
21. Lynch, J. H.: Nebraska M. J. **19**:20, 1924.
22. Worter, C. W.: Tr. Am. Proct. Soc. **29**:13, 1929.
23. Owen, H. R.: S. Clin. North America **14**:117, 1934.
24. Glenn, F.: New England J. Med. **207**:544, 1932.
25. Cattell, R. B., and Stoller, L. W.: New England J. Med. **206**:110, 1932.

tion was in good hands and up to 35 per cent in other cases. Rogers and Hall (first and second series [13]) in a comprehensive study in which they found 19 per cent recurrences in original cases and 75 per cent in acute and recurrent ones concluded that one must avoid radical excision to assure satisfactory results. They depended on the removal of all diseased tissue present at the time of operation and present in the wound during the process of healing.

Residual symptoms in the scar after radical excision have also been mentioned. Lahey [26] recommended the pedicle flap to obviate this undesirable sequela. Rogers and Hall [13] reported residual symptoms, such as pain, discomfort and numbness, in 39 per cent of patients operated on.

In our series of 11 cases of pilonidal sinus observed during a period of four years there was neither a recurrence of the sinus after the operation nor a complaint of any untoward scar symptoms.

TREATMENT

Three types of operation are employed for the eradication of this lesion:

1. Nonambulant radical excision. This, of course, is the method of choice for the majority of surgeons. There are various modifications of the same procedure, such as primary closure, partial closure, open packing and a combination of these.

2. Ambulant radical excision. This method appears to be an improvement and is certainly worthy of favorable comment. Two different procedures have been employed, with a striking resemblance in the manner of approach. There is a deliberate attempt to conserve skin and at the same time to excise extensively the underlying tissue. This in our opinion is an important and logical course to pursue. Primary suture has been employed by Ferguson [16] in selected cases in which the patient was well prepared, with only 1 recurrence in 21 cases. This single recurrence was observed in a patient in whom the acuteness of the condition was regarded by Ferguson as a contraindication to immediate intervention. The cautery method described by Stanton has been employed by Rogers and Hall [13] in a series of 50 cases, with no recurrences and excellent results.

3. Ambulant simple incision followed by repeated applications of a sclerosing solution. This is, in our opinion, the most satisfactory and effective means available for the eradication of this annoying condition. It is entirely ambulant, is painless, requires no sedation and leads to no recurrence or residual symptoms. Even the most compli-

26. Lahey, F. H.: Surg., Gynec. & Obst. **48**:109, 1929.

cated sinus, consisting of many lateral tracts and pouches, lends itself to this treatment. There is an immediate relief from pain and a gradually increasing freedom from odor and discharge. The fact that infection is immediately checked or entirely eliminated after the first few applications of the solution is of inestimable value. This observation seems to refute the generally accepted theory that the proximity of the anus to the operative wound is the cause of persistent infection. This condition is probably due to the retention of infected tissue in the wound.

Most of the tract is usually obliterated, and the remaining portion is free of infection and completely fixed after a few treatments. If incomplete healing does occur, further incision and excision may be accomplished ambulantly without fear of recurrence or of any other untoward effect. We resorted to subsequent incisions when unexpected bridging had occurred or when a tract had been overlooked, and in some cases to the excision of portions of the lesion for microscopic study, without in any way retarding the healing progress of the wound.

The preparation used is a modification of Carnoy's solution, consisting of absolute alcohol 6 cc., chloroform 3 cc., glacial acetic acid 1 cc. and ferric chloride 1 Gm. This solution was described and suggested by Cutler and Zollinger [27] in 1933.

Despite condemnation by Colp [18] and the unfortunate experience of Rogers and Hall [13] in 1 case, we feel that the method is sound surgically and is superior to all other methods proposed. Smiley [20] reported success in the treatment of the condition in 3 simple cases over a period of six months; we have successfully treated it in 11 cases, not selected, over a period of four years. In 8 of these the treatment was given in the office; in 1 it was given in a tuberculosis sanatorium, and in the other 2 it was given in a state hospital for the insane.

Ambulant nonoperative treatment by galvanic current was employed with success in 1 case by Maillard.[28] Crookall [29] resorted to the use of silver nitrate flakes and a silver nitrate stick in 2 cases with satisfactory results. The treatment, however, was cumbersome, and the patient complained of severe pain and hemorrhage.

TECHNIC OF THE SCLEROSING TREATMENT

This method of treatment is employed exclusively in all cases of pilonidal sinus, whether the condition is acute or chronic and whether it is simple or complicated.

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27. Cutler, E. C., and Zollinger, R.: Am. J. Surg. **19**:411, 1933.

28. Maillard, E. R.: Nonsurgical Treatment of Pilonidal Cyst, J. A. M. A. **93**:1383 (Nov. 2) 1929.

29. Crookall, A.: Tr. Am. Proct. Soc. **28**:32, 1928.

Either iodized poppyseed oil or paste of bismuth N. F. is usually injected into the main orifice, and a roentgenogram is taken to determine the extent of the lesion. Bismuth paste seems to be the more satisfactory, especially if there is more than one orifice. The secondary orifices should be sutured or plugged with the finger when the paste is being forced into the tract. It is well to note here that we do not use any dye to delineate the tracts. In our opinion methylene blue or any other delineating agent is entirely unnecessary, but if one wishes to outline the tracts bismuth paste will admirably serve the purpose and because of its viscosity will not penetrate normal tissue.

The patient is then placed in the prone position again, and the region is prepared in the usual manner for the operation. The skin is infiltrated with a 2 per cent solution of procaine hydrochloride along the midline and if necessary to one side or the other for a short distance to facilitate the incision and the exposure of lateral tracts. (In some cases we resorted to block anesthesia, which is also eminently satisfactory.) The type of incision may be the T shaped, the crucial or the vertical, depending entirely on the extent of the lesion. The wound is not guttered, but it is extremely important to uncover all tracts. The wound is then tightly packed with iodoform gauze (treated with petrolatum, if desired), care being taken to fill every tract, pouch and crevice. The patient is then discharged. Irrigation of the wound as suggested by Cutler and Zollinger [27] is entirely omitted.

In two or three days after the initial incision the sclerosing treatment is instituted. The pack is removed carefully and gently; the table is tilted so as to lower the upper half of the body to an angle of about 66 degrees, and the wound is completely filled with a 2 per cent solution of butyn for five minutes (anesthesia). The skin around the wound is covered with petrolatum or a zinc oxide ointment. The butyn solution is then wiped up by means of cotton pledgets or gauze, and the wound is filled completely with a modified Carnoy solution, which is allowed to remain for five or ten minutes (usually only five minutes). This tans the tissue and acts as an effective hemostatic. The excess solution is then removed, and the wound is packed carefully, as before, with iodoform gauze. A proper dressing is applied. This process is repeated every three or four days until complete healing ensues.

It is imperative to prevent bridging over by frequently and carefully testing the forming scar for any areas of defective healing. We found it necessary occasionally to incise two or three times to insure the formation of a solid scar. Light curettage may be necessary, but if it is too vigorously done or too often repeated it may retard the healing of the wound.

The most satisfactory dressing (fig. 3), in our opinion, is applied as follows: The packed wound is covered with a few layers of sterile

gauze about 2 inches (5 cm.) square. Strips of adhesive plaster 1 inch (2.5 cm.) wide and 4 inches (10 cm.) long are so placed that one half of the width covers the dressing and the other half the skin. Four strips are used for the entire dressing.

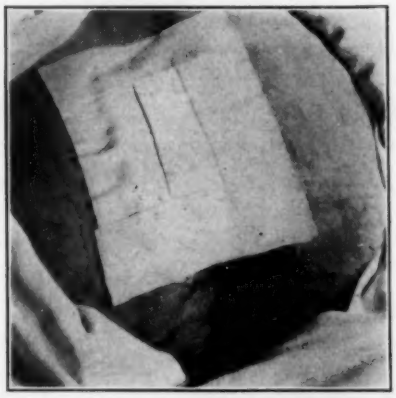

Fig. 3.—Suitable dressing, simple and sufficient for the absorption of all discharges. It is comfortable, and the patient's underclothing is seldom soiled.

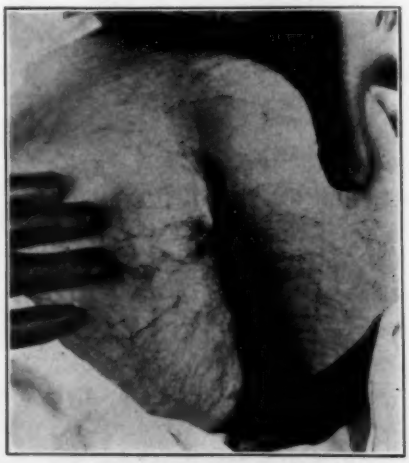

Fig. 4.—Thin, linear white scar left after healing. In every case the wound healed completely. The scar is firm, movable and free from residual symptoms.

The bleeding in the cases in our series was insignificant and was completely controlled by the hemostatic properties of the solution and by packing, which is of prime importance in this procedure. The postoperative pain was trivial. A few patients complained of some discomfort for an hour or two after the treatment, but no patient complained of disabling pain. A remarkable feature was the total absence of purulent discharge in most cases after the first application of the sclerosing

solution. A persistent discharge or odor, which disappeared after a few treatments, was noted in 2 cases. There was rapid filling in of healthy granulation tissue. The minimum time required for complete healing was about four weeks, and the maximum was ten weeks. The number of treatments varied from a minimum of eight to a maximum of twenty-two. The total average number of treatments after the initial incision was 16.2. There was absolutely no hospitalization, no loss of time from work or pleasure and no recurrence. In every instance a firm, simple, freely movable incisional scar formed, completely free from residual symptoms.

REPORT OF CASES

We submit a brief abstract of 4 of the 11 cases in which the condition was treated and observed during a period of four years and complete and permanent cure resulted.

CASE 1.—H. K., a man aged 23, had a history of trauma six months prior to the formation of an abscess which ruptured spontaneously and drained continuously for a period of two years.

The patient was underweight and tuberculous. He was not hirsute. No previous treatment had been given. He complained of discharge, of odor and of pain and discomfort when sitting or walking. Examination disclosed a single skin-lined orifice in the midline, leading into a tract about 4 cm. long. Purulent discharge and odor were present, but there was no hair. A primary vertical incision and two subsequent incisions of the tract were made, and nineteen applications of the solution were administered during a period of sixty-nine days (July 10 to Sept. 17, 1933). There was no discharge or odor, and very little pain was noticed after the first treatment. There was a freely movable scar. There were no complaints of residual symptoms. No recurrence was observed.

CASE 2.—C. F., a man aged 24, had a history of trauma seven years prior to the onset of an acute abscess. The abscess was "lanced" and treated as a "carbuncle" three times between 1927 and 1929.

The patient was obese and hairy. He complained of periodic discharge of pus, of odor, of pain, of discomfort when sitting or walking and of the presence of loose strands of hair extruding from the opening in the wound. Examination disclosed a single skin-lined discharging orifice in the midline and two secondary orifices about 2 cm. above, one to the right and one to the left. A tuft of hair was seen. Swelling and discoloration were present. There was a tract about 5 cm. long. A primary crucial incision followed by seventeen applications of the solution during a period of sixty-one days (June 24 to Aug. 25, 1934) gave excellent results. There was no discharge, no odor and no pain after the first four treatments. There was a deep saddle-like scar, freely movable and entirely symptomless. No recurrence was observed.

CASE 3.—H. K., a man aged 34, had no previous history of trauma. He suddenly noticed a "boil" which ruptured spontaneously and drained periodically for a period of two years. No previous treatment had been received.

The patient was obese and hairy. He complained of pain, discomfort on sitting or walking and of periodic purulent discharge. A discharging skin-lined orifice was found in the midline, and a secondary orifice was seen about 3 cm. above and to the left. No hair was noticed. A primary vertical incision was made fol-

lowed by nine applications of the solution over a period of thirty days (Aug. 4 to Sept. 4, 1935). The patient had some discomfort for periods varying from one to three hours following the first two or three treatments, but no discomfort was felt afterward. The results were excellent; no pain, discharge or odor was present after the third treatment. No residual symptoms were noticed in the freely movable scar. There was no recurrence.

CASE 4.—G. C., a woman aged 18, had a history of trauma four years prior to the onset of an acute abscess which ruptured spontaneously one year prior to this treatment. No previous treatment had been received.

The patient was well developed but not obese. She complained of periodic purulent discharge and of pain and discomfort when sitting or walking. Examination disclosed two discharging orifices, one (skin lined) in the midline and the other about 4 cm. to the right. The tract measured about 5 cm. in length. A primary vertical incision was made with a lateral incision to the right, exposing the tract and a pouch. No subsequent incisions were made. Eighteen applications of the sclerosing solution were given over a period of seventy-six days (Oct. 7 to Dec. 23, 1935). The results were excellent. The patient had no pain after the first treatment; there was no discharge and no odor. There was a freely movable scar. No residual symptoms were observed.

SUMMARY AND CONCLUSIONS

A brief review is presented of the essential features of the subject of pilonidal sinus and of its controversial phases.

A thorough study of the anus, the rectum and the colon of every patient is imperative before a diagnosis of pilonidal sinus is made and the sclerosing treatment instituted.

Eleven patients afflicted with pilonidal sinus were treated with simple incision and the application of a sclerosing solution during the past four years.

Every patient was ambulant during the entire course of treatment, and no hospitalization, loss of time or extraordinary expenditure was required.

The treatment was painless except for discomfort experienced by the patient for a very short period after the application of the solution in the early stages of the treatment.

A very small linear and movable scar formed, free from all residual symptoms.

There was no recurrence in any of the cases in this series.

Pilonidal sinus is, in our opinion, particularly amenable to the sclerosing treatment, and the essential requirements are simple but must be judiciously fulfilled to assure success.

We are convinced that this procedure for the eradication of this annoying lesion is vastly superior to any other heretofore employed.

The solution of butyn was supplied by the Abbott Laboratories, North Chicago, Ill.

185 North Wabash Avenue.

A NEW APPARATUS FOR MAINTAINING HOT COMPRESSES AT CONSTANT TEMPERATURE

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That hot wet dressings are definitely of value in the treatment of certain conditions is an unquestioned fact. Also it is readily acknowledged that the efficiency of the compress is in direct ratio to the constancy of its temperature. How to maintain hot wet compresses at constant temperature has been the problem for solution. While making daily rounds of the wards I have found compresses too cold or, on occasions, have encountered evidence of their having been applied too hot. It was this circumstance that prompted me in 1933 to start experimental work on the subject. The inadequacy of the present methods is experienced in all hospitals, large or small, and this experience is no reflection on a busy nursing staff.

Five objectives for which one should strive in using a hot compress were first listed as follows:

1. Constant or nearly constant temperature at the surface of the skin.
2. A simple method for keeping the compress moist.
3. A means of checking the temperature at the surface of the skin at all times.
4. Safety with minimum attention from the nurse or attendant.
5. Comfort for the patient.

As 108 to 110 F. was the generally accepted temperature at which hot compresses should be applied, this temperature was first assumed as the objective. An ordinary electric heating pad was obtained and its thermostats set at 120 F. It was felt that 10 to 12 degrees would approximately compensate for heat lost by the absorptive action of the body, by radiation or by the insulation of the cloth compress between the heating unit and the skin. This heating unit was then covered with rubber to make it waterproof.

Experiments with different fabrics soon showed that outing flannel was best suited for the cloth part of the compress, because of its ability

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to absorb solutions. A standard thickness was deemed necessary for all cloth compresses used. Four ply flannel compresses were then constructed because this thickness seemed to be approximately correct.

The heating unit was preheated by plugging it into a socket and waiting until it attained its maximum temperature—120 F. Then the outing flannel compress was dipped into a 5 per cent solution of magnesium sulfate at 112 F. and placed on the skin with a thermomenter between it and the skin. The heating unit was then superimposed and fastened in place by ties. I was somewhat surprised to note that in several repetitions of the experiment the temperature at the surface of the skin persistently dropped to 100 F. or less in ten to fifteen minutes. Consideration was then given to the physiologic factors regulating the heat in the body. It became evident that more heat was necessary in the heating unit to overcome the refrigerating action of the body. Therefore, the thermostats were gradually "set up" in an effort to attain a *mass* of heat which when liberated from the resistance coil in the heating unit would be sufficient to overcome the absorption of heat by the body and to keep the compress at the surface of the skin at 108 to 110 F. This objective was finally accomplished in the case of a certain normal person, at one particular part of the body, when the thermostats were set at approximately 170 F. That most of the loss of heat was not due to radiation was demonstrated when the apparatus was placed on an inanimate object, such as the top of a table. It was noticed that the temperature between the flannel compress and the top of the table soon approached 170 F.

Several heating units were then built and experiments made on different parts of the body in the same person and on corresponding surfaces of the body in different persons. It soon became evident that no two persons and no two parts of the body in the same person absorb the same amount of heat. The nature of the pathologic process also was found to be a definite factor in determining how much heat would be absorbed. For normal persons the amount of heat necessary to obtain a constant temperature at the surface of the skin seemed to depend on the following factors primarily:

1. The size of the body and its blood volume.
2. The temperature and humidity of the room.
3. The vascularity of the specific part of the body being heated and of the adjacent structures.
4. The pressure of the compress against the heated part.

Because of these factors it was concluded that in order to produce the desired temperature the mass of heat applied to any given area of the body must be readily alterable within wide limits. Therefore, a

rheostat of sufficient potential resistance to allow for these variable factors was introduced into the system.

Automatic thermostats to control the heat in conformity with this requirement were considered but given up. For reasons already mentioned, the control would have to be at the surface of the skin. This was felt to be mechanically and economically impracticable even if such a control could be developed.

At this stage of investigation a definite stumbling block was encountered, namely, the discovery of hot spots in the compresses. These resulted in a superficial burn in 1 case. They were easily located experimentally and were much more noticeable in the double compress to be described later. In these double compresses in which the hand, with the fingers spread, was inserted between two units, the temperature between the fingers soon built up to approach that in the resistance coil above and beneath it. The reason for this was simply that in the areas of the cloth compress not in contact with the skin there was no absorbing mechanism to carry a part of the heat away. If the hand was moved so that these areas came in contact with the skin, the latter was then exposed to increased temperature, often sufficient to cause disintegration of the epithelium. The same difficulty was encountered to a lesser degree with the single compresses because of increase in the mass of wire at the turning points of the wiring. Furthermore, a peripheral part of the applied compress often became raised from the corresponding area of the skin with a resultant rise in its temperature.

Various methods for overcoming this difficulty were the object of experiment for over a year. Finally it was found that when the heating unit was wired in the design of an involute coil (fig. 1) no hot spots developed. The involute coil concentrated the *mass of heat* liberated at the center of the compress with gradual diminution toward the periphery, although the *temperature* of the resistance wire was the same throughout. When the compress was in use, the thermometer lying at the surface of the skin directly beneath the area of the greatest concentration of heat gave an accurate reading of the maximum temperature and eliminated all danger.

The four ply flannel compress had been previously found to remain moist though heated for from eight to ten hours. This compress was fitted with a cloth sleeve to contain the thermometer on the side next to the surface of the skin. This measure was adopted for two reasons: 1. The thermometer itself when in direct apposition with the skin provided an excellent insulator to the portion of the skin with which it was in contact. 2. By means of the sleeve the thermometer was held in place so that its bulb lay at the point in the system where the heat was most concentrated—viz., the center. Of course the cloth sleeve was somewhat of an insulator itself, but when only one thickness of cloth was

used there was little difference between the temperature recorded by the thermometer and the temperature at the surface of the skin.

Several changes have been found necessary since the first apparatus was completed. Ordinary thermometers were at first used, but changes in temperature were noted during the process of extracting the thermometer and reading it. Therefore, special thermometers were designed,

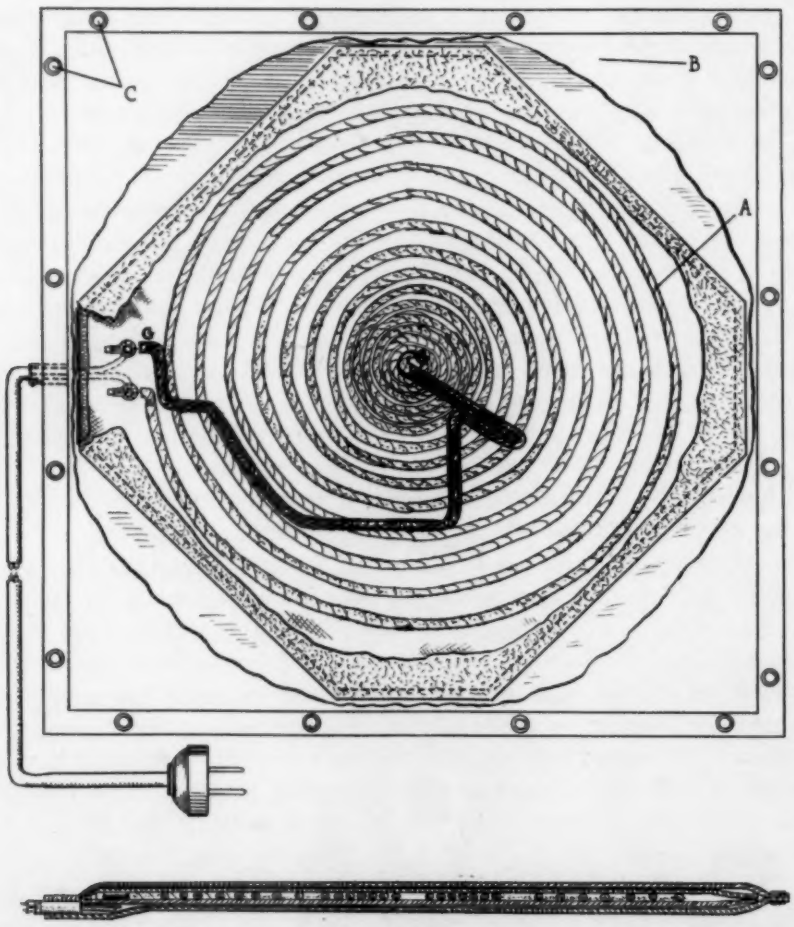

Fig. 1.—Heating unit wired in the design of an involute coil.

calibrated in such a manner that they could be read without removal from the sleeve. These thermometers revealed at a glance the temperature at the surface of the skin in the region of the greatest concentration of heat. They were metal jacketed to insure against breakage. However, the metal jackets were later given up because of the increased pressure due to their weight and because of their tendency to conduct

and concentrate heat. This tendency in 1 case was responsible for a slight burn, which, though it occurred in an area which was comparatively avascular because of previous trauma, revealed the necessity for removal of this causative factor. Another important change was the separating by heavy insulation of the wire leading out of the system *G-G*, (fig. 1) from the rest of the coil.

The following is a description of the perfected apparatus: Figure 1 shows the wiring of the heating unit. This, as is readily noted, is in the design of an involute coil. The heat liberated is concentrated at the center and diminishes at the periphery, although the temperature of the wire is constant throughout. In operation the central part lies directly over the center of the outing flannel compress, where the bulb of the thermometer is placed. This wiring is labeled *A*. *B* is the water-proof covering, of such material and construction that it will tolerate heat to 200 F. *C* represents the grommets along the edges of the covering for the insertion of ties to hold the compress in place. If for any reason this covering should be perforated during operation and the solution allowed to surround the wire coil, the latter will not cause any appreciable shock to the patient because of the low amperage used.

Figure 2 shows the single outing flannel compress with the thermometer, *D*, inserted in its sleeve, *E*, on the surface of the skin or wound. This compress will absorb a relatively large amount of solution and will remain moist though heated for eight to ten hours. Figure 3 shows the double outing flannel compress for the hand. The same principle may be used for other parts, such as the forearm or the elbow. However, when a double compress is used, two heating coils, with two independent rheostats (shown mounted in the same rheostat box in the photographs), and two thermometers are required.

The reason for this requirement is that because of the pressure on the lower coil exerted by the weight of the hand or other part less heat is necessary in that unit to maintain the desired temperature at the surface of the skin. The cloth compresses are easily autoclaved and applied sterile. Figure 4 shows the double and the single unit in cross section. Figure 5 shows the single rheostat. The photographs in figures 6 and 7, show the single, large and small, and the double unit in operation.

Many attempts have previously been made by others to construct such an apparatus. These have, so far as I know, been given up because of burns in certain cases. The combined physiologic and mechanical difficulties responsible for these burns have, I believe, been overcome by the combination of the involute coil, the cloth compress of standard thickness, the sleeve for the thermometer, the thermometer which tells the temperature at the surface of the skin or wound at the point where

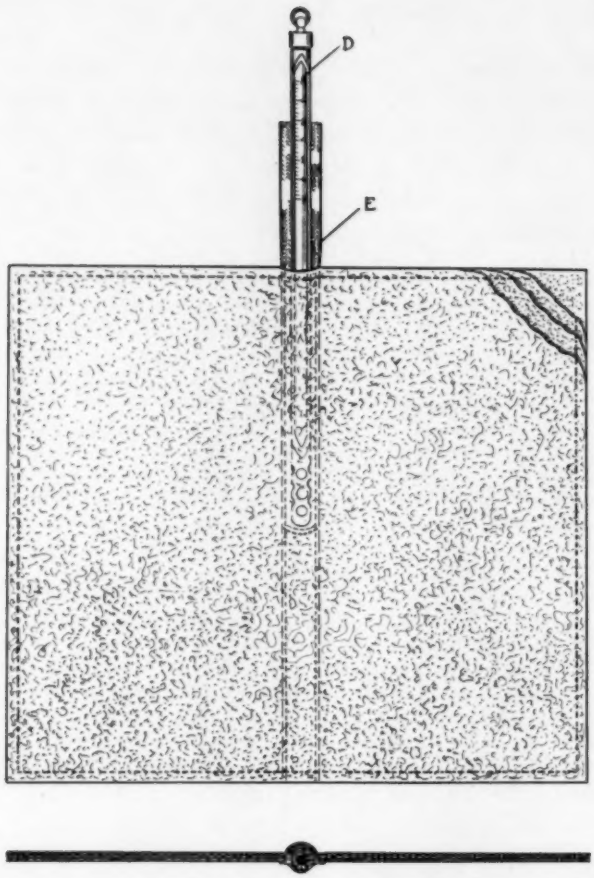

Fig. 2.—Single outing flannel compress with the thermometer inserted in its sleeve.

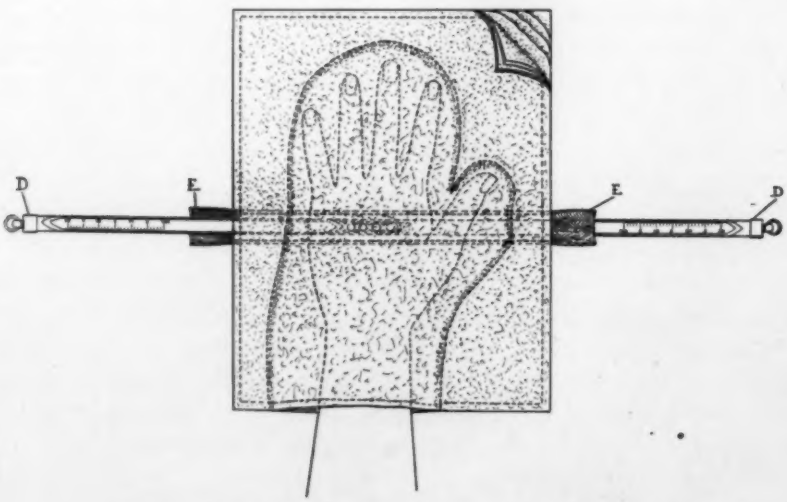

Fig. 3.—Double outing flannel compress for the hand.

the mass of heat is the greatest and the rheostat which allows the quantity of heat to be altered. I propose that the apparatus be made in various sizes suitable for application to different parts of the body.

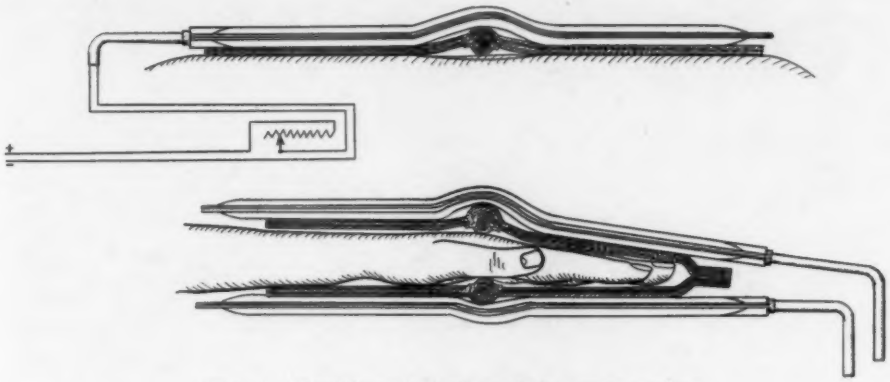

Fig. 4.—Double and single unit in cross section.

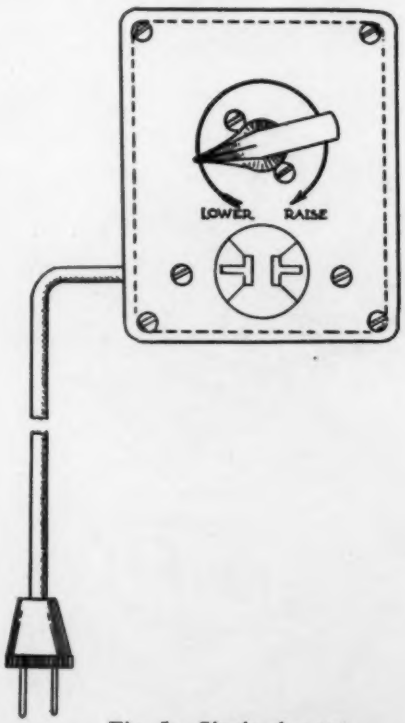

Fig. 5.—Single rheostat.

Various solutions have been used for moistening the compress. Magnesium sulfate in a 5 to 10 per cent solution has been the medicament of choice in most cases of cellulitis. However, for cellulitis about

Fig. 6.—Large and small single unit in operation.

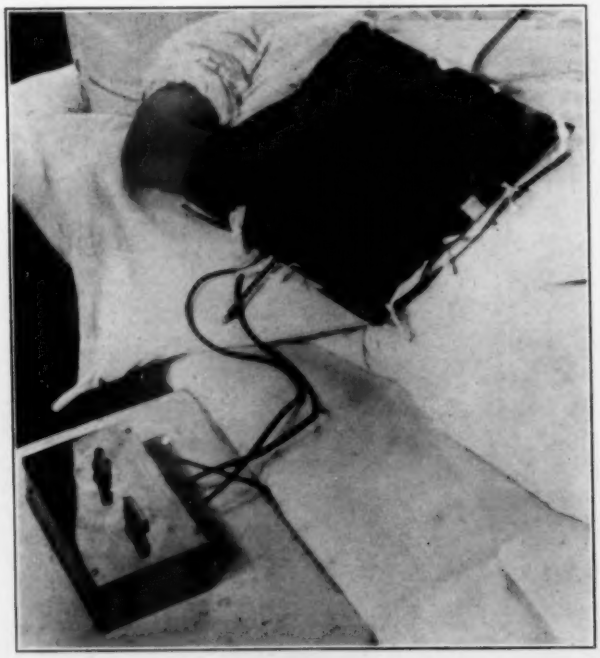

Fig. 7.—Double unit in operation.

the eye, boric acid was used. This solution was used also for varicose ulcers. On infected wounds (open) a mild germicide, such as diluted solution of sodium hypochlorite U.S.P. or azochloramine, has been the solution of choice. Physiologic solution of sodium chloride has been used after grafting skin.

CLINICAL EXPERIENCE

During the last four years approximately 30 patients have been treated with the apparatus in its various stages of development. The experience with these patients seems to indicate that properly controlled wet heat has more therapeutic value than may have been previously supposed. Excellent results have been obtained in treating chronically infected wounds. For such wounds the compress has been utilized in two ways: (1) to clear up the infection and to stimulate fresh, clean granulations, and (2) to stimulate the "taking" of subsequent skin grafts to the wound. Varicose ulcers of long duration appear to respond equally well to this form of treatment. Superficial pyogenic infections seem to become localized and heal more quickly than when other methods alone are used.

The temperature at which the compresses should be maintained appears to vary with the pathologic conditions. In cases of acute pyogenic cellulitis 108 to 112 F. seems optimum; in cases of chronic cellulitis, such as that associated with osteomyelitis, lower temperatures for longer periods are advisable (104 to 108 F.). In cases of the latter type I have kept the compresses on constantly for as long as thirty days before skin grafting. Varicose ulcers require about the same temperature for approximately seven or eight days before skin grafting. Skin grafts respond better at still lower temperatures (102 to 104 F.). More can be said as to the length of time for which the compress should be kept in place and the temperature advisable for various conditions after more patients have been treated.

The exact physiologicobacteriochemical reaction to the local application of wet heat is not clearly understood. It offers an interesting subject for study. An attempt may be made to experiment further on this reaction, and if so it will be reported, together with a series of cases, at a later date.

This apparatus in no way precludes the necessity for keen surgical judgment, particularly in cases of acute streptococcic cellulitis. Furthermore, it should be used only under the close supervision of the physician. It is not offered in competition with other forms of treatment but rather as a means of supplementing existing methods of therapy.

BILATERAL COLLAPSE THERAPY IN THE TREATMENT OF PULMONARY TUBERCULOSIS

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SECAUCUS, N. J.

Although bilateral artificial pneumothorax was introduced about a quarter of a century ago, there still exist wide differences of opinion as to the value of this form of therapy in the treatment of pulmonary tuberculosis and as to the type of condition to be selected for its use. When bilateral application of such a measure as phrenicotomy or thoracoplasty or a combination of these procedures with or without pneumothorax is considered, the variation in opinion is still wider.

In view of these circumstances it is felt that the addition of another paper to the literature, recording my experience in a comparatively

TABLE 1.—*Bilateral Pneumothorax—Availability of Pleural Space*

Type of Space	Number of Cases
Bilateral space	152
Unilateral space	49
No space	10
Total number of cases	211

large series of cases observed over a period as long as five years, will add clarity to the subject. This study comprises, in all, 211 cases in which pneumothorax was attempted bilaterally, with results as regards the availability of a pleural space as revealed in table 1. As will be shown later, some of the patients for whom the pneumothorax was abandoned or unobtainable on one or both sides were subjected to the more radical surgical measures.

Before going into detail as to the fate of the 211 patients, I should like to make clear the basis on which the selection of patients for collapse therapy was made. Having discussed this subject thoroughly elsewhere,[1] I wish merely to state, first, that for no patient in this group was collapse therapy used unless cavitation was present and, second, that artificial

From the Hudson County Tuberculosis Hospital and Sanatorium.

Read at the Annual Meeting of the American Academy of Tuberculosis Physicians, Atlantic City, N. J., June 8, 1937.

1. Potter, B. P.: Modern Concepts on the Collapse Therapy of Tuberculous Pulmonary Cavities, Am. Rev. Tuberc. **31**:499, 1935.

pneumothorax was the first measure of choice. Interestingly, cavities of moderate or large size were present bilaterally on the patients' admission to the hospital in the vast majority of instances; in the remainder, necrosis took place in the contralateral lung after a unilateral effective collapse had existed for some time. Still a further point of interest is the fact that pulmonary tuberculosis in 95 per cent of the patients was classed as far advanced according to the standards of the National Tuberculosis Association.

BILATERAL PNEUMOTHORAX

A pleural space was encountered bilaterally in 152 of the 211 cases. While this incidence may appear high, especially when one considers the stage in which the disease was treated, it is nevertheless closely similar to that found in 520 cases of attempted unilateral pneumothorax. As will be seen later, this close parallelism between bilateral and unilateral pneumothorax exhibits itself again when the question of the number of effective collapses and the complications are taken into account.

TABLE 2.—*Type of Pneumothorax in 152 Cases of Bilateral Pneumothorax*

Simultaneous	119
Alternating	33

It is important to know the type of pneumothorax under consideration when the problems of bilateral collapse are discussed because, for obvious reasons, an alternating pneumothorax presents, with few exceptions, difficulties no different from those encountered in the unilateral form. As is shown in table 2, and as was to be expected from the type of cases selected, simultaneous pneumothorax is the predominant feature of this study.

While pneumothorax was induced on either one side or the other immediately or within two months after the patient's admission to the hospital, the interval between bilateralization averaged ten months but was as low as one month in a few instances. In retrospect I feel that this average interval could have been reduced to eight months or possibly even less, but I lean strongly toward a reasonably liberal period of observation between the induction of the first pneumothorax and that of the second, for the following reasons: In the first place, it is desirable that an effective collapse be either present or reasonably certain of occurrence without further intervention before one attacks the contralateral lung; for it has been my experience (as well as that of others) that pneumonolysis, if it should become necessary, may be hazardous in the presence of a bilateral pneumothorax. In the second place, I

have found that varying portions of relatively uninvolved lung may have to be sacrificed during the establishment of satisfactory pneumothorax. However, such sacrifice should not be continued once an effective collapse is achieved, as optimum functional respiratory integrity should be restored by permitting the reexpansion of the uninvolved portions before contralateral collapse is induced. Under such conditions the patient is able to withstand with little or no discomfort any further reduction of lung volume that may be entailed. Finally, as the more involved lung becomes effectively collapsed, the lesion on the opposite side may become controlled, and thus collapse may be obviated.

Of course, one is often compelled to deviate from this ideal practice either because of progression of the lesion in the uncollapsed lung or because of the development of pleurisy, threatening obliteration of the corresponding pleural space. When it is further remembered that, in spite of the presence of offending adhesions in 60 to 70 per cent of the cases and of the fact that their severance was indicated in only 4 per cent, it becomes evident that the second pneumothorax in many instances was induced while the first was still ineffective.

Another point for consideration concerns the side to be selected for the first pneumothorax. A review of the literature on bilateral pneumothorax indicates general agreement that the lung showing the more active lesion should be favored initially. While on the whole this criterion is useful, there are cases of a bilateral process in which the difference in degree of activity is difficult to determine, especially if there are no comparative roentgenograms, as is often the case. Furthermore, with most of the patients with simultaneous pneumothorax in the group under present consideration the problem centered about the cavities in the lungs, involving such questions as their size, their location and the character of the pericavernous infiltrate. Another factor is a history of roentgenologic evidence of recent pleural involvement, which warrants the early induction of pneumothorax to obviate the loss of a possible free pleural space. It is obvious, therefore, that the question of which lung is to be chosen for initial collapse will depend on conclusions drawn after due consideration has been given to the factors just cited.

As for the actual technic, my experience may be cited with respect to several controversial issues. It is generally conceded that a pneumothorax should not be established bilaterally at the same sitting, on the same day or even in the same week. It is conceivable that because of profuse uncontrolled hemorrhage of undeterminable pulmonary origin bilateral collapse may become urgent, but this must be a very rare occurrence, as evidenced by the fact that I have not encountered it in a single instance.

After bilateralization of the pneumothorax, the question arises whether refills should be given at the same sitting. While the patient is in the hospital and is available for frequent observation or treatment, refills may be confined to one side at a time. Once he has been discharged, however, I do not hesitate to insufflate both sides at the same sitting. In fact, it is generally preferable to do so, in order to assure the maintenance of nearly equal intrapleural pressures. In several instances in which this point was overlooked, the patients noticed various symptoms, such as wheezing in the chest, irritating dry cough or shortness of breath, all of which disappeared with equalization of the intrapleural pressures and the return of the mediastinal structures, if displaced, to the midline. As will be shown later, no untoward complications have been noted from this practice.

The other features of the technic differ in no respect from those that apply to unilateral pneumothorax. I wish to stress, however, that it is essential that the collapse be confined as far as is possible to the diseased portions of the lungs. This can be best accomplished during the patient's residence in the hospital by refills of small quantities (150 to 250 cc.) of air three times a week, and after discharge by weekly refills of not more than 350 cc. of air.

The adequacy of any surgical measure in the arrest or "cure" of pulmonary tuberculosis must be judged also by its capacity to return the patient to a state of health compatible with social usefulness. Mere obliteration of the cavity and prolongation of life with the patient left in a state of invalidism is not in my opinion a satisfactory result. Although it might be expected that bilateral collapse would place greater limitations on the patient's useful existence, my experience reveals that this is not actually so.

As may be seen from table 3, 45, or 79 per cent, of the 57 patients in whom an effective bilateral pneumothorax was achieved are working, able to work or ambulatory; and these results closely parallel those obtained in a much larger series of cases of unilateral pneumothorax.

When the frequency of the effectiveness of bilateral pneumothorax is compared with that of the same procedure in cases of unilateral cavitation, close similarity again demonstrates itself. Thus, in the series represented in table 3 the collapse became effective bilaterally by pneumothorax in 57 of the 152 cases, showing an incidence of 37 per cent as against 38 per cent of instances of closure of the cavity in another group of 398 patients in whom the lesion presented a problem of unilateral collapse therapy.

The complications differ in no respect from those encountered with unilateral pneumothorax. Differences of opinion have arisen only as regards their comparative frequency. So far as pleural effusions are

concerned, I have had an incidence of 50 per cent in cases of bilateral pneumothorax as against 34 per cent with unilateral pneumothorax. However, the incidence of effusion per pneumothorax was only 25 per cent. The fluid became empyematous in about an equal number of instances (8 per cent). Superimposed spontaneous pneumothorax of clinical significance was noted in only 4 patients, all of whom responded favorably to underwater drainage.

Before concluding the subject of bilateral pneumothorax, it may be of interest to inquire about the anatomic status of the lungs which were permitted to reexpand after an effective collapse had existed and

TABLE 3.—*Clinical Status of 152 Patients in Whom a Bilateral Pleural Space Was Found**

Groups	Working or Able to Work	Ambulant	Improved	Unimproved	Dead	Total
Bilateral effective pneumothorax.....	28	17	5	3	4	57†
Unilateral effective pneumothorax; contralateral pneumothorax abandoned..	2	9	4	2	0	17
Bilateral pneumothorax abandoned.....	0	5	0	21	50	76

* The remaining 2 patients with original bilateral pleural space are included in table 5.
† Collapse was made effective by pneumonolysis in 4 cases and by supplementary phrenicotomy in 1.

TABLE 4.—*Anatomic Status of Reexpanded Lungs*

Both Lungs Reinflated			One Lung Reinflated		
Bilateral Closed Lesion	Unilateral Closed Lesion	Total Number of Cases	Closed Lesion	Open Lesion	Total Number of Cases
13*	4	17	9	0	9

* In 2 cases collapse was made effective on one side by thoracoplasty and thoracoplasty plus phrenicotomy, respectively, after an ineffective pneumothorax had been abandoned.

of the condition of which a follow-up is available for periods varying from several months to four years. The data in the 26 cases analyzed in table 4 are drawn from the patients comprising the first two groups in table 3. It is evident that bilateral pneumothorax if effective serves not only as an immediate control measure but also eventually leads to arrest of the disease. What is even more impressive is the fact that the incidence of residual closed lesions after reexpansion in this group closely parallels that found in my patients with unilateral pneumothorax.

COMBINED COLLAPSE THERAPY OTHER THAN EXCLUSIVE PNEUMOTHORAX

When obliteration of bilateral cavitation is sought by measures other than exclusive pneumothorax, the complexity of the problem is increased proportionately as the more radical surgical procedures are utilized in

the combination. This is especially noticeable when forms of collapse which are either permanent (thoracoplasty) or not immediately reversible (phrenicotomy) are considered. The importance, therefore, of careful selection of the procedures and of the optimum time of their application is obvious.

Table 5 shows briefly the various types of combined collapse therapy that were used in 28 selected cases for patients in whom a pleural space was absent unilaterally or bilaterally (table 1) or in whom the pneumothorax was abandoned on one or both sides (table 3). The results show that patients fare better if the measures in the combination are

TABLE 5.—*Clinical and Anatomic Results in Combined Collapse Therapy Other Than Exclusive Pneumothorax*

Form of Combination	Anatomic Result of Collapse	Working or Ambulant	Improved	Worse	Dead	Total
Pneumothorax on one side, thoracoplasty and phrenicotomy on other (alternating)	Bilateral effective	1	0	0	0	1
Pneumothorax on one side, thoracoplasty on other side (3 alternating)	Bilateral effective	2	0	0	0	2
	Unilateral effective	0	1	0	5*	6
	Bilateral ineffective	0	0	1	0	1
Pneumothorax on one side, phrenicotomy on other (in 2, alternating; in 5, phrenicotomy supplementary to bilateral pneumothorax)	Bilateral effective	4	0	0	0	4
	Unilateral effective	4	0	0	1	5
	Bilateral ineffective	0	0	0	3	3
Bilateral phrenicotomy (all alternating)	Bilateral ineffective	1	0	0	1†	2
	Unilateral effective	0	0	0	1*	1
Phrenicotomy on one side, thoracoplasty on other side (all alternating)	Bilateral effective	2	0	0	0	2
	Unilateral effective	1[a]	0	0	1[a]	a
Bilateral thoracoplasty	Unilateral effective	0	0	0	1	1
Totals		14	1	1	12	28

* Postoperative deaths.
† The patients later underwent thoracoplasty and appear in the table by the designation "a."

applied alternately. Of course, this is possible only when an effective collapse on one side is achieved by such a reversible procedure as pneumothorax or temporary phrenic interruption. This point is strikingly brought out by the figures shown in the second form of combination in the table. It will be noted that the condition of the 3 patients subjected to thoracoplasty on one side after the contralateral lung had been permitted to reexpand is improved, whereas 5 postoperative deaths occurred among the patients in whom the procedures were utilized simultaneously. While wound infection was an added factor in the causation of death in 2 cases, respiratory embarrassment played the predominant role in 3. It is for this reason that I believe that bilateral thoracoplasty, unless the lesion in the lung is truly apical, can rarely be successful. For the sake of completeness, it should be said that as time goes on the number

of cases similar to those analyzed in table 5 will be somewhat increased, but in the vast majority of the cases in the groups from which these cases were taken the prognosis is not good as long as an open lesion remains.

CONCLUSION

In conclusion, I wish to stress that of all forms of bilateral collapse therapy bilateral pneumothorax is the most effective measure. Evidence has been offered which reveals that the results with this procedure are as good as those obtained by unilateral pneumothorax and the frequency of complications is about the same with the two procedures. It is therefore felt that there should be no hesitation in giving all patients presenting cavitation in both lungs the benefit of bilateral pneumothorax. Other procedures or combinations of procedures besides bilateral pneumothorax, especially when applied simultaneously, offer good results in relatively few cases; and because of the hazards involved the selection of patients must be carefully made.

DUODENOGASTRIC INTUSSUSCEPTION

ITS CLINICAL APPLICATION AND RESULTS

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For the past five years my colleagues and I have been experimenting on dogs in an effort to determine some of the factors involved in the causation of peptic ulcer.[1] In these experiments the pyloric sphincter of the stomach was divided by a longitudinal incision down to the mucosa. Then the pars superior duodeni was invaginated into the antrum pyloricum. This procedure produced duodenogastric intussusception. The ulcer-bearing area (the pyloric end of the stomach and the first portion of the duodenum) was thereby transplanted into a new and more highly acid environment. Eight months after operation the invaginated portion remained in place and was found to be morphologically normal. In other words, a living transplant of Brunner's glands had been placed in the pyloric antrum.

Studies made with regard to acids, mucin and the emptying time led to the following conclusions:

(*a*) Brunner's glands have two secretions—a local protective mucin and a systemic acid-stimulating hormone.

(*b*) Hydrochloric acid stimulates the local production of mucin as well as gastrin, which in turn assures the necessary hydrochloric acid for this stimulation, thereby perpetuating the cycle.

(*c*) The adventitious duodenal mucous membrane in these experiments did not show ulcer even with increased acidity and rapid emptying time. This was explained as due to the action of the defensive mechanism (mucin).

Ulcers were next produced in normal dogs by using toxic doses of cinchophen. These animals had only a slightly higher acid content but a much larger amount of mucin than normal. Since ulcers develop almost uniformly in control animals, it was thought that the amount of mucin, although increased, was insufficient to protect the mucous membrane. Ulcers could be produced in the stomach and the duodenum

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From the Department of Surgery, Indiana University School of Medicine.

1. Berman, J. K., and Baxter, N. E.: Duodenogastric Intussusception: An Experimental Study of Peptic Ulcer, Arch. Surg. **33**:1-18 (July) 1936.

of dogs protected by duodenogastric intussusception after the administration of toxic doses of cinchophen but much less frequently and without perforation.

Our experiments proved the value of reenforcing and using the pyloric end of the stomach rather than sacrificing it, as is done in pylorectomy or gastrectomy. The operation of duodenogastric intussusception creates an artificial plica circularis (valvula conniventes) and delimits jetting of acid chyme. By transplanting Brunner's glands adequate mucin protection is afforded. This procedure also reenforces and immobilizes the pylorus. This is proved by the fact that peristaltic waves are not seen in this region. The ulcer is thereby permitted to heal.

We concluded that (*a*) because of its safety and ease of performance in suitable cases, duodenogastric intussusception is an aid in the surgical treatment of chronic peptic ulcer and that (*b*) if scarring of the pylorus is marked or if the ulcer is on the gastric side, excision of the ulcer with division of the pyloric sphincter followed by duodenogastric intussusception is the operation of choice.

INDICATIONS FOR SURGICAL INTERVENTION IN CASES OF ULCER

In general, patients with ulcer may be divided into three large groups: The first group includes those who respond to medical management. Although accurate statistics are difficult to evolve because so many ulcers heal undiagnosed, we feel that the great majority of patients with peptic ulcer belong in this group. The second group includes those who respond to surgical therapy. One cannot be sure of the response that will be shown by a patient to surgical treatment, but the indications for operation are clear. They may be dogmatically listed as follows: (1) perforated peptic ulcer,[2] (2) ulcer with obstruction, (3) ulcer with repeated hemorrhage [3] (at least one repetition) and (4) chronic ulcer which will not respond to intensive medical care, especially if on the gastric side. For this group of patients almost any of the accepted surgical procedures, whether it is a pyloroplasty, gastroenterostomy or gastrectomy, if followed by good medical supervision will effect a cure.

The third group of patients may be called ulcer formers.[4] This term may be misleading because any patient who has once had a peptic ulcer becomes an ulcer former under proper stimulation.[4] However, here

2. Berman, J. K.: Some Consideration of Probable Exciting Factor in Perforated Peptic Ulcer, J. Indiana M. A. **26**:416-419 (Sept.) 1933.

3. Goldman, L.: Gross Hemorrhage from Peptic Ulcer: Its Morbidity, Mortality, and Treatment, J. A. M. A. **107**:1537-1542 (Nov. 7) 1936.

4. David, V.: Personal communication to the author.

it is desired to refer to the patients in whom, in spite of medical and surgical care, recurrent ulcers accompanied by complications usually develop. It is for the latter group of patients that duodenogastric intussusception seems most promising; and since, as has been stated, one cannot foretell the outcome in these cases, we feel that the most desirable operation is a conservative one which does not sacrifice tissue and which has permanent value. Such we believe is duodenogastric intussusception.

TECHNICS FOR OPERATION

Although the procedure as originally described in our previous paper [1] can be done in selected cases, we found that it is usually necessary to combine it with other forms of pyloroplasty. The original operation consisted in freeing the greater and lesser curvatures of the stomach and duodenum by dividing the hepatogastric and hepatoduodenal ligaments and the gastrocolic ligaments with the greater omentum. This is carried out from the upper portion of the antrum to a point about 1 to 1½ inches (2.5 to 4 cm.) distal to the pylorus, the extent varying with the length of the first portion of the duodenum and its mobilizability. An incision is then made down to the mucous membrane, as in the Rammstedt pyloroplasty. Then the operation is completed by pulling the stomach down over the duodenum and anchoring it with two or three tiers of interrupted silk sutures (fig. 1). However, the operation may be combined with various forms of pyloroplasty:

1. The anterior two thirds of the pylorus is resected (fig. 2).
2. If the ulcer is on the gastric side it may be excised, and the pylorus may be divided longitudinally and sewed transversely (fig. 3).
3. Or the pylorus may be divided and sewed transversely (fig. 4).
4. If the ulcer is on the posterior side and is tightly adherent to the pancreas, the pylorus may be divided, and then the ulcer may be cauterized, removed or not molested; this is followed by transverse suture and invagination of most of the circumference of the duodenum (fig. 5).
5. V`resection of the ulcer on the lesser curvature is followed by division of the pylorus (fig. 6).

It is readily seen that this procedure may be used in conjunction with most types of pyloroplasty and that in addition to the lines of protecting sutures, immobilizing and reenforcing the ulcer-bearing area, it creates a living transplant of Brunner's glands supplying the protective mucin.

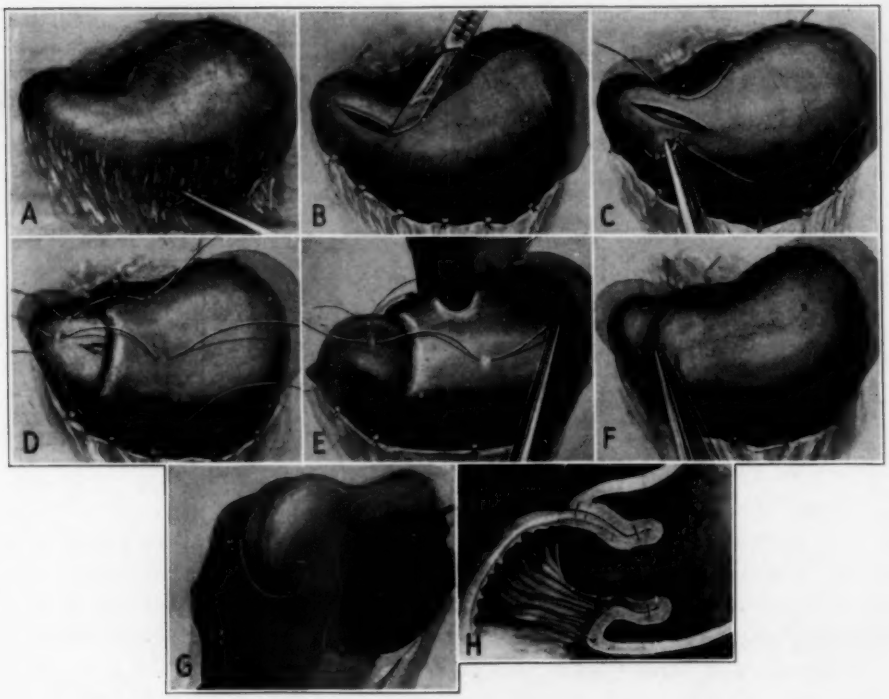

Fig 1.—Duodenogastric intussusception. *A*, division of the hepatogastric and hepatoduodenal ligaments and the gastrocolic ligament with the greater omentum; *B*, longitudinal incision of the pylorus in the manner of a Rammstedt pyloroplasty; *C*, the first tier of sutures in place so as to form a duodenogastric intussusception; *D*, the second tier of sutures; *E*, the second tier of sutures on the posterior side; *F*, extra sutures placed around the circumference to make the suture line secure; *G*, testing the patency of the pylorus with the thumb and forefinger; *H*, cross section showing the completed operation of duodenogastric intussusception.

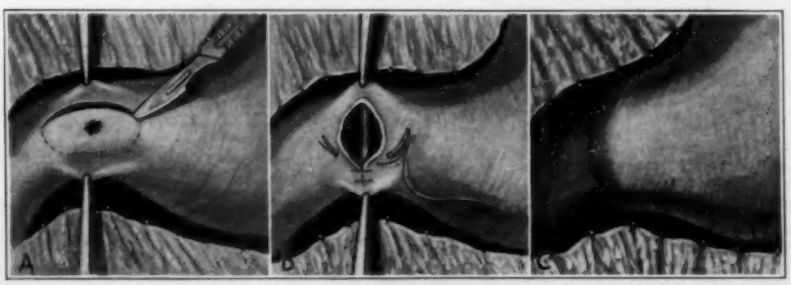

Fig. 2.—*A*, the resection of the anterior two thirds of the pylorus; *B*, transverse suture of the pylorus; *C*, duodenogastric intussusception after the pylorus has been sutured transversely.

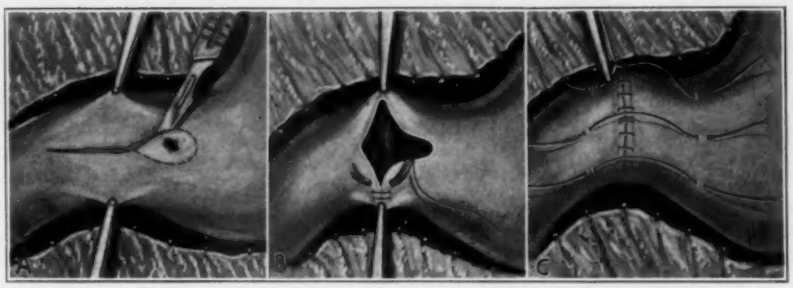

Fig. 3.—*A*, excision of the gastric ulcer, with longitudinal incision of the pylorus; *B*, transverse suture of the pylorus; *C*, duodenogastric intussusception. The first tier of sutures is complete.

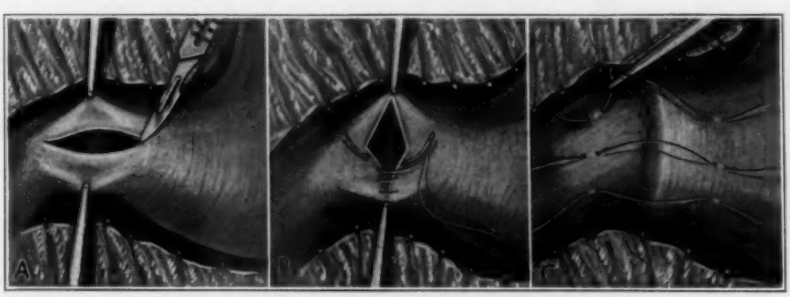

Fig. 4.—*A*, longitudinal incision of the pylorus; *B*, transverse suture; *C*, duodenogastric intussusception. The first tier of sutures is complete. The second tier of sutures is in place.

Fig. 5.—*A*, longitudinal incision of the pylorus (the ulcer is seen on the posterior side); *B*, transverse suture of the longitudinal incision; *C*, duodenogastric intussusception of approximately four fifths of the circumference (posterior view; the ulcer is adherent to the pancreas).

REVIEW OF CASES

We have carried out this operation on 5 patients thus far. The first operation was performed on Feb. 2, 1936. It will be noted that we waited six months between the first and the second and also between the second and the third operation. This was done to insure the reliability of the operation. As our technic improves, we feel that it may be used in most cases of surgical ulcer.

CASE 1.—Mr. J. M. M., aged 62, a laborer, was admitted to the Long Hospital on Feb. 2, 1936, complaining of severe abdominal pain. This had begun suddenly twenty hours before admission to the hospital. Although there was no previous history of ulcer, he stated that his stomach had been sore for three days prior

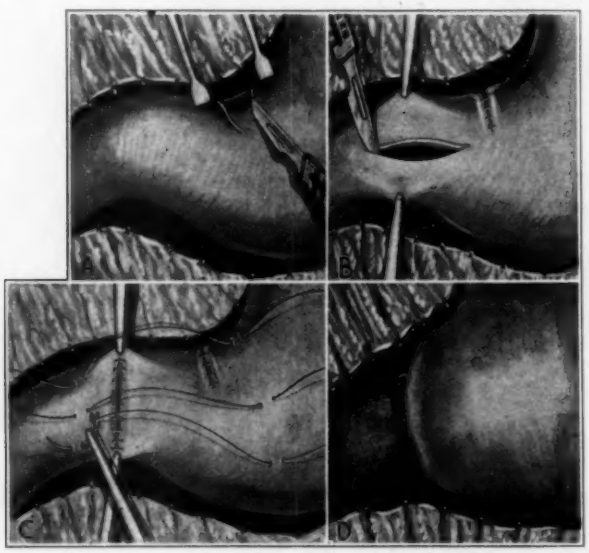

Fig. 6.—*A*, a V resection of the gastric ulcer on the lesser curvature; *B*, transverse suture of the resected area and longitudinal incision of the pylorus; *C*, duodenogastric intussusception after transverse suture of the pylorus (the first tier of sutures is in place,; *D*, duodenogastric intussusception completed.

to the onset of the illness. The abdomen was extremely rigid, and there was marked tenderness in the epigastrium. The blood counts and urinalyses gave normal results. The Kline test for syphilis gave a negative reaction. Roentgenographic examination revealed pneumoperitoneum. A diagnosis of perforated peptic ulcer was made, and he was operated on within one hour after entry.

With the patient under ether anesthesia a right upper paramedian incision was made. When the peritoneum was incised, free air escaped. The duodenum was found to be markedly inflamed and covered with a thick plastic exudate. A small perforated ulcer was situated on the anterior wall of the duodenum, and a second ulcer was felt below this. The hepatogastric, hepatoduodenal and gastrocolic ligaments were divided up to the upper portion of the pyloric antrum and down to a point about 1½ inches (4 cm.) below the pylorus, thereby mobilizing this portion

of the stomach and duodenum. The pyloric sphincter was divided longitudinally down to the mucous membrane in the manner of a Rammstedt pyloroplasty. Then duodenogastric intussusception was done, two tiers of no. 0 chromic catgut suture being used (fig. 1)). The greater omentum was placed over the field of operation, and the abdomen was closed without drainage.

The patient made an uneventful recovery and was discharged from the hospital on February 21. On March 9 he was in good health, with no symptoms; the values for acids were within normal limits, and the value for mucin was 0.9 mg. per cubic centimeter. A barium sulfate meal was given, and the report was as follows: Preliminary fluoroscopic examination of the chest showed a heart of borderline size. The ascending aorta was slightly widened. No abnormal pulsations were visualized. The peribronchial markings were increased. There was good excursion of the diaphragm. Studies of the gastrointestinal tract showed normal fillings of a J type of stomach. Rugae were regular throughout. The distal end of the pylorus and the bulb were deformed, probably owing to the previous operative procedure. A portion of the duodenal bulb had been invaginated into the distal portion of the pylorus, leaving only the terminal end of the first

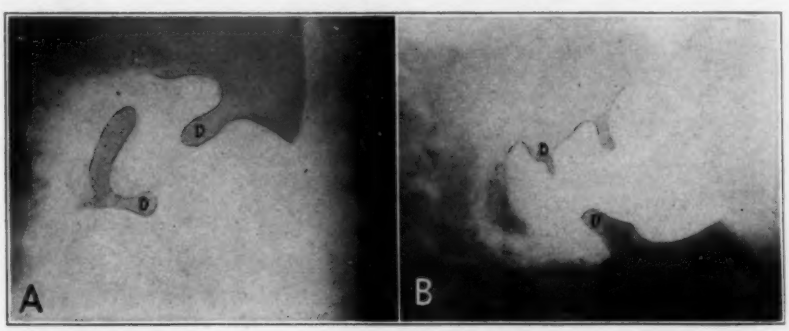

Fig. 7 (case 1).—*A*, roentgenogram (retouched) showing the duodenum invaginated into the pyloric antrum (immediately after operation); *B*, six months later, showing the permanency of the duodenogastric intussusception. Note the widened pylorus. *D* indicates duodenum.

portion of the duodenum well visualized. This was flattened and broadened, and the distal end of the pylorus, which had been brought down, was considerably wider than normal. The second portion of the duodenum was well visualized. The operative procedure apparently caused mild deformity in the greater curvature of the distal end of the pylorus. At six hours the stomach was empty, and the head of the meal was in the transverse colon. The patient was given a second barium meal in order to permit the rechecking of the findings (fig. 7 *A*).

On September 9 he was asked to return, and another barium meal was given, the report being as follows: There was considerable improvement in the condition of the distal end of the pylorus and the bulb. At six hours the stomach was empty, and the head of the meal was in the transverse colon. The pyloroplasty was apparently functioning well (fig. 7 *B*).

The patient has remained free from symptoms.

Case 2.—Mr. A. U., aged 55, an unemployed laborer, was admitted to the Long Hospital on June 16, 1936, with complaints of loss of weight, insomnia, and pain and discomfort in the abdomen. His past history revealed that he had had pain

in the abdomen since 1924. A medical regimen for two years failed to relieve his symptoms. On March 2, he was operated on. The surgeon said he felt that the lesion was an inoperable carcinoma, and after taking a lymph gland for biopsy he closed the abdomen without further surgical intervention. The lymph gland proved to be an inflammatory enlargement. The patient improved somewhat after this procedure but was readmitted to the Long Hospital on June 16 with recurrence of the symptoms.

Physical examination showed that he had lost a great amount of weight and that he had a palpable thyroid gland and extreme tenderness in the epigastrium.

Laboratory examination showed: urine, normal; phenolsulfonphthalein test, 70 per cent for two hours; red blood cells, 4,170,000; hemoglobin, 12 to 13 Gm.; white blood cells, 6,200 to 13,250; serologic tests, negative reaction; stools, 1 plus to 4 plus blood; basal metabolic rate, —1 per cent. An alcohol and histamine test [5] showed high acidity, up to 73 per cent free hydrochloric acid, total acid,

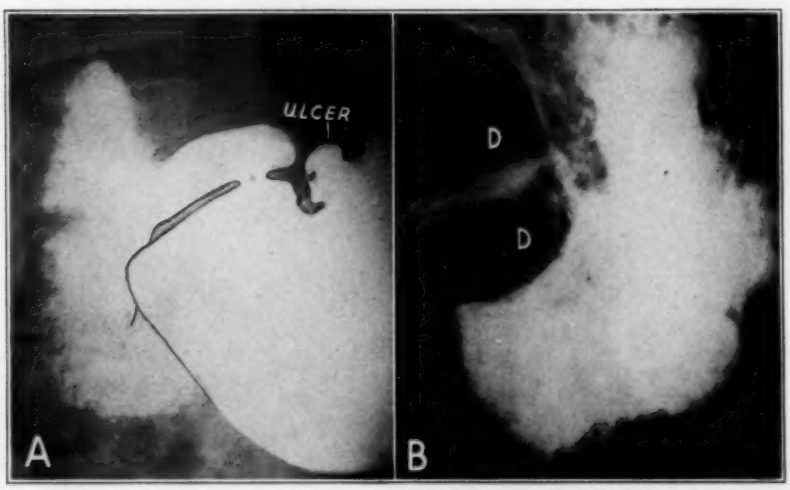

Fig. 8 (case 2).—*A*, roentgenogram (retouched) taken before operation, showing the peptic ulcer on the lesser curvature and the defects of the bulb; *B*, seventeen days after operation, at which the ulcer was removed and the duodenum invaginated.

79 per cent, and lactic acid, 0. Blood was present in all specimens. The p_H was 5.5. No determination of mucin was made prior to operation. The roentgenographic examination showed a large penetrating ulcer on the lesser curvature, with complete retention at the end of six hours (fig 8*A*). He was placed on Sippy managment but made no progress, as determined clinically, by roentgenographic study and by gastric analyses.

5. Alcohol and histamine tests are performed in the Long Hospital as follows: After the stomach is emptied, the patient is given 200 cc. of 7 per cent alcohol. Then 0.5 mg. of histamine is given subcutaneously (0.2 mg. is given if the patient is a woman). The stomach contents are then aspirated every fifteen minutes for one hour. The average normal value agrees with that reported by Lerman and his associates (Lerman, J.; Pierce, F. D., and Brogan, A. J.: Gastric Acidity in Normal Individuals, J. Clin. Investigation **11**:155-165 [Jan.] 1932): about 41 per cent free hydrochloric acid and about 51 per cent total acid.

On August 1 the patient was operated on, and a large ulcer was seen on the lesser curvature. This was adherent to the under surface of the liver. The operative note is as follows: With the patient under ether anesthesia the abdomen was entered through a right upper paramedian incision. This was done because a left paramedian incision had been made five months previously in an attempt to extirpate the ulcer. Dense adhesions were encountered in the peritoneal cavity to such an extent that considerable time elapsed before mobilization of the stomach could be accomplished. When the stomach was brought into view it was found to contain a gastric ulcer which had perforated and which had become adherent to the under surface of the left lobe of the liver. The duodenum was found to be free from ulcer and easily mobilizable. The pylorus, however, was obstructed by bands of adhesions. The ulcer-bearing area was carefully dissected loose from the liver. The pyloric antrum and pars superior duodeni were mobilized by division of the hepatogastric and hepatoduodenal ligaments and the gastrocolic omentum. The ulcer was prepyloric and was on the lesser curvature. A V-shaped resection of the lesser curvature was performed which included the ulcer and the surrounding callus. This was closed transversely with a continuous no. 00 chromic catgut suture. The duodenum was then divided longitudinally and sutured transversely; then it was brought up into the lumen of the stomach, producing duodenogastric intussusception. Thus the suture line of the excised ulcer was turned under by means of the interrupted silk sutures placed around the entire circumference of the stomach. A second line of sutures, bringing the stomach further down over the duodenum, was then placed anteriorly and posteriorly. The completed operation invaginated the duodenum into the pyloric antrum, with a patent pylorus, as tested with the thumb and forefinger. The great omentum was placed over the field of operation, and the abdomen was closed without drainage, the following sutures being used: for peritoneum, no. 0 chromic catgut; for muscle, no. 1 plain catgut; for fascia, no. 0 chromic catgut, and for skin, interrupted silk (fig. 6).

After this operation a careful study of the gastric contents was made as recovered through the Levine tube. It was found that when the patient was permitted water by mouth and the contents were then aspirated, the analyses were difficult to interpret because of dilution. However, we arrived at an accurate determination by giving the patient nothing by mouth for six hours and aspirating all the gastric juices during this time. On August 4 (third postoperative day) the mucin determination was 22.2 mg. per hundred cubic centimeters. During twenty-four hours a total of 328.8 mg. of mucin was secreted. The value for free hydrochloric acid was 18; and that for total acid, 55. There was a small amount of blood. These studies were rechecked on August 12 and 14 (eleventh and thirteenth postoperative days). At this time the following values were obtained: free hydrochloric acid, 11; total acid, 25, and mucin, 61 mg., per hundred cubic centimeters. The patient made a good recovery. The pathologic report on the resected tissue showed chronic gastric ulcer, and the report on the microsection was as follows: The mucosa of the stomach dipped down slightly into the ulcerating area. It gradually became atrophic as it blended with the coagulum which made up the base of the ulcer. There was no evidence of carcinoma of the mucosa. The base of the ulcer consisted of a heavy layer of connective tissue. Part of this was necrotic, but the deeper portions appeared viable. Many accumulations of lymphocytes, plasma cells and polymorphonuclears were seen in this connective tissue layer. On August 18 a recheck of the gastric condition was made after the ingestion of a barium meal, and the results of the operation were clearly shown in the roentgenograms (fig. 8*B*). The patient returned to

the outpatient department three months later, at which time he made a vague complaint of general pains over the entire body. On March 1, 1937, a letter written to the patient brought no reply; however, his family physician reported him to be in good health. On June 4 another letter was written to him inviting him to return to the outpatient department if he still had any symptoms. He did not respond to this, although he lived but a short distance from Indianapolis. We assumed, therefore, that he was in a good state of health at that time.

Summary.—This patient with recurrent chronic gastric ulcer had had three years of medical management and a previous operation for ulcer. After the operation herein described he was clinically improved, and the acid values returned to normal. Although the roentgenogram showed some retention immediately after the operation, this condition evidently did not persist because no symptoms of retention appeared. The pylorus had probably been opened by the lateral pull of the wall of the stomach. As far as is known now, the patient remains clinically well.

Case 3.—Mr. H. W., aged 37, a laborer, was admitted to the Long Hospital on May 8, 1937. His chief complaint was of pain in the epigastrium, which was not relieved by careful diet and alkaline powders.

Sixteen years before his admission to the hospital appendectomy was performed elsewhere. For the past six years he had had pain in the epigastrium coming on about two hours after meals. This was relieved by food.

The patient was a thin man with a scar in the right lower quadrant of the abdomen. There was tenderness in the epigastrium with muscle spasm. In the medical department a careful study was made, and it was found that he had pyelitis and cystitis and that the urine was loaded with pus and red blood cells. However, repeated cystoscopic examination revealed no stones. The white blood cell count varied from 6,400 to 14,750. Roentgenographic examinations were repeatedly made, and an opaque shadow was always seen in the right upper quadrant. This proved later to be caused by the gallbladder, which was filled with stones. Tetraiodophenolphthalein sodium was injected, but the gallbladder was not visualized. Barium meal revealed normal filling of a rather large stomach. There was a large niche showing retention on the posterior wall of the lesser curvature of the fundus of the stomach which was probably due to ulcer (fig. 9 *A*). Slight tenderness was noted over this area. At twenty-four hours there was normal movement of the meal. Gastric analyses made prior to operation showed: free hydrochloric acid, 80; total acid, 86 (average); blood, 0; mucin, 0; p_H of gastric contents, 4. The stools repeatedly showed blood. The phenolsulfonphthalein test showed: first fifteen minutes, a 17.5 per cent output, and first half hour, a 32.5 per cent output.

On April 13 operation was performed, and the following note was made: With the patient under ether anesthesia the abdomen was entered through a right upper paramedian incision. Exploration of the abdomen revealed a duodenal ulcer on the lesser curvature just below the pylorus. The gallbladder was markedly distended and was found to contain one stone.[6] The right kidney was slightly

6. Three of these patients had gallstones. In 1932 we presented a paper before the Indiana University Post-Graduate Course on the incidence of gallstones and peptic ulcer. We found this association to be present in about 5 per cent of cases. Whereas cholelithiasis may be accompanied by a low or high gastric acid content (this explains relief with sodium bicarbonate in some and dilute hydrochloric acid in others), in the patients with ulcer the values for acids were uniformly high. These patients were to have operations on the gallbladder later.

enlarged and was relatively low but not movable. The pyloric antrum, the pylorus and the first portion of the duodenum were mobilized by division of the hepatogastric, hepatoduodenal and gastrocolic omentum between ligatures. The ulcer was excised together with a portion of the pylorus, which was then sutured transversely with no. 0 chromic catgut sutures, thereby widening the pyloric canal. The stomach was brought down over the duodenum, in the manner of a duodenogastric intussusception, by two tiers of interrupted silk suture. The omentum was brought over the field of operation, and the abdomen was closed without drainage, with no. 0 chromic catgut sutures in the fascial and interrupted silk sutures in the skin (fig. 2.).

On April 19 (fifth postoperative day) an alcohol and histamine meal was given with the following results: free hydrochloric acid, 51, and total acid, 65; the mucin content was not determined. However, this test was repeated on April 30, and the results showed a maximum free hydrochloric acid content after the alcohol and histamine meal of 51 and a hydrochloric acid content during fasting of 0. There was no blood, and the total acid content was 66. The value for mucin was 72 mg. per hundred cubic centimeters. The pathologic report

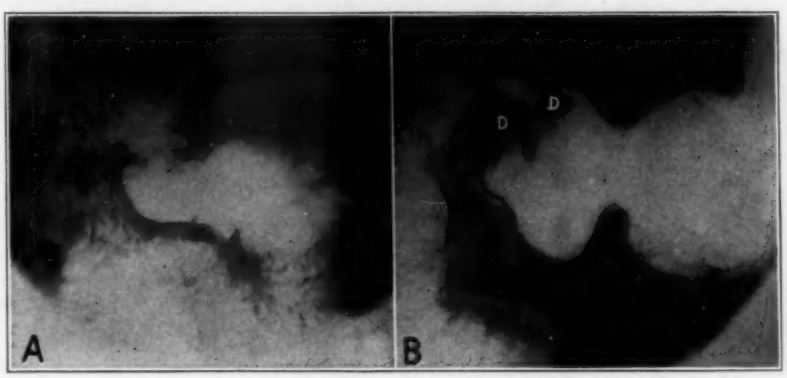

Fig. 9 (case 3).—*A*, roentgenogram (retouched) taken before operation, showing defects of the bulb; *B*, sixteen days after operation, showing the duodenogastric intussusception. Note the peristaltic wave. This does not follow through the invaginated portion but is carried on into the duodenum.

of the tissue removed at operation was as follows: duodenal ulcer, with no indication of malignancy; one lymph node showed nonspecific hyperplastic changes.

Roentgen examination of the gastrointestinal tract on April 30 showed normal filling of the stomach. There was marked deformity of the distal end of the pylorus and the bulb (apparently from the operative procedure of duodenogastric intussusception). There was good emptying of the stomach. Slight dilatation of the second and third portions of the duodenum was noted. At six hours there was a slight trace of barium in the stomach, and the head of the meal was in the transverse colon. At twenty-four hours there was a normal movement of the meal (fig. 9*B*).

This patient was discharged from the hospital on May 1 in an excellent state of health and completely relieved of his symptoms.

He was admitted on May 8 for a check-up. He was entirely free from symptoms, and gastric analysis showed during fasting free hydrochloric acid of 0 and total acid of 10; after the alcohol and histamine meal the total acid was 61, with free hydrochloric acid of 51.

Summary.—This patient had a chronic gastric ulcer with complicating cholecystitis and cholelithiasis, pyelitis and cystitis. Medical management over a long period failed to relieve his symptoms. After the operation as herein described the patient was relieved of all gastric symptoms, the values for acids returned to normal limits [7] and the follow-up study showed him to be clinically well.

Case 4.—Mrs. N. W., aged 52, a widow, was admitted to the Long Hospital on May 22, 1937. She complained of vomiting for the past four weeks, loss of weight (26 pounds [11.8 Kg.]) and arthritis. She had been operated on elsewhere seven months previously for a perforated ulcer, with satisfactory recovery; but she vomited just before discharge from the hospital and since that time had vomited occasionally. She had vomited every day for the past three weeks. Arthritis had been present for the past four years.

Physical examination showed a scar over the upper portion of the right rectus muscle, beneath which was a firm mass. There was no tenderness or rigidity; the abdomen was scaphoid.

The blood pressure on entry was 105 systolic and 70 diastolic. The red blood cell count was 4,610,000 and the white blood cell count 7,500. The stool contained 3 plus blood on May 31. Urinalyses showed specimens ranging from those with 6 plus cells to those loaded with pus.

Analysis of the stomach contents on May 27 showed 3 plus blood, and a p_H of 6. Gastric analysis on June 2 showed a total acid of 30, free hydrochloric acid of 10 and 94 mg. of mucin per hundred cubic centimeters.

Roentgen examination of the gastrointestinal tract after ingestion of a barium meal on May 24 showed normal filling of a large ptotic stomach. Peristalsis was exceedingly vigorous. Considerable time elapsed before the barium passed beyond the pyloric end of the stomach. The bulb was small but did not appear to be greatly deformed. The second and third portions of the duodenum were well visualized. There did not appear to be any abnormality in this area. However, there was about 70 per cent retention at five hours. At twenty-four hours there was normal progress of the meal, with 15 per cent retention in the stomach. The diagnosis was partial obstruction, possibly due to ulcer, although none was visualized (fig. 10 *A*).

An operation was performed on June 4. With the patient under ether anesthesia the abdomen was opened through a right paramedian incision mesial to the scar of the previous operation. The stomach and duodenum were densely adherent to the parietal peritoneum so that careful dissection had to be made to reach the pylorus. Exploration revealed a thickened gallbladder filled with small calculi. The pancreas was found to be normal. The common duct was not enlarged and apparently was without obstruction. The duodenum had one large diverticulum on its superior margin just distal to the pylorus. The pylorus was thickened and narrowed down to the size of a lead pencil. The scar of the previous ulcer was found; it was on the gastric side and was not active. After the pyloric antrum and pars superior duodeni had been carefully freed, all bleeding areas were tied doubly with transfixed ligatures on both sides. The pylorus was then incised longitudinally, and careful inspection was made of the duodenum, which showed the diverticulum previously referred to. The ampulla of Vater could be seen after the incision had been prolonged, and bile was found to be freely spurting into the duodenum. The mucosa was pale. The lumen of the stomach was explored and was found to be without new growth or active ulcer. The rugae were small and

7. This coincides with the findings in our experimental work. The values for acids remain about normal, but the amount of mucin is increased.

seemed to be absent in places. The mucous membrane was pale and smooth, but in spots small hemorrhagic areas were seen. The longitudinal incision was sutured transversely with no. 0 plain catgut. This was turned in by means of interrupted silk sutures placed entirely around its circumference. Two tiers of these sutures were used, forming a duodenogastric intussusception. The omentum was brought down over the field of operation, and the abdomen was closed in layers without drainage with a no. 0 plain catgut continuous suture for peritoneum, no. 0 plain interruped sutures on the rectus muscle and no. 1 chromic catgut cross stitch interrupted sutures on fascia. A black silk mattress on edge suture was used for the skin (fig. 4).

The postoperative course was uncomplicated.

Gastric analysis on June 19 (fifteenth postoperative day) showed free hydrochloric acid of 0, total acid of 20, no lactic acid, no blood and no significant

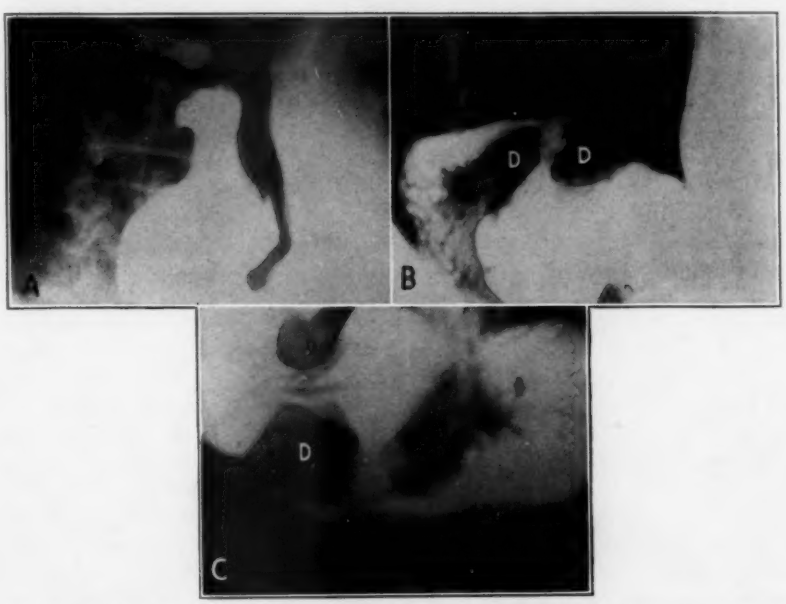

Fig. 10 (case 4).—*A*, roentgenogram taken before operation, showing the J type of ptotic stomach and the almost completely obstructed pylorus; *B*, seventeenth day after operation (note the improved position of the stomach and the invaginated duodenum); *C*, closer view of the duodenogastric intussusception.

organism. Alcohol and histamine gastric analysis on June 26 showed: free hydrochloric acid, 0; total acid, 14; lactic acid, 0; blood, a trace; p_H 4, and mucin, 89 mg. per hundred cubic centimeter. Gastric analysis (alcohol and histamine) on June 30 showed: free hydrochloric acid, 32; total acid, 38; lactic acid, 0; blood; p_H, 8, and mucin, 89 mg. per hundred cubic centimeters.

Postoperative roentgen examination of the gastrointestinal tract after the ingestion of a barium meal showed good filling of a rather large stomach; narrowing of the distal end of the pylorus; considerable irritability over this area; persistent deformity of the duodenum, pylorus and bulb, which is found in duodenogastric intussusception (operative procedure), and mild dilatation of the second and

third portions of the duodenum. At six hours there was a trace of barium in the stomach, and the head of the meal was progressing normally. At twenty-four hours the colon was nearly empty.

The patient was discharged from the hospital on June 30 free from all gastrointestinal symptoms.

CASE 5.—Mrs. C. E., a housewife, aged 41, was admitted to the Long Hospital on June 22, 1937. She complained of pain in the epigastrium, left shoulder, neck and face; loss of weight (70 pounds [31.8 Kg.] in two and one-half years), and nausea and vomiting. She had had pain in the left shoulder and in the left side of the neck for eight to ten years. There had been some gastric discomfort during this time, and she complained of extreme nervousness.

Physical findings included evidence of loss of weight, an edematous throat, a lipoma at the insertion of the left deltoid, no masses or tenderness in the abdomen, hyperactive reflexes and retroversion of the uterus. The blood pressure on entry was 150 systolic and 100 diastolic, the temperature 98.6 F. and the pulse 90.

Laboratory examination showed: hemoglobin, 10 Gm.; red blood cells, 3,220,000 to 3,400,000, and white blood cells 7,500 to 8,050. Urinalyses showed: albumin, slight trace, and pus cells, occasional to 20. The phenolsulfonphthalein test showed an output which varied from 5 to 15 per cent for fifteen minutes. On entry gastric analyses showed: free hydrochloric acid, 74; total acid, 109, and blood, plus. The patient was placed on the Sippy management. Gastric analyses showed: on June 25, free hydrochloric acid, 59; total acid, 78, and blood, plus; on June 26, free hydrochloric acid, 54; total acid, 88, and blood, plus; on June 27, free hydrochloric acid, 10; total acid, 79, and blood plus; on June 28, free hydrochloric acid, 49; total acid, 56 and blood, 0. Alcohol and histamine gastric analysis on July 3 showed: free hydrochloric acid, 0; total acid, 14; lactic acid, 52; blood, 0, and mucin, 0. The Mosenthal test showed a variation in the specific gravity from 1.008 to 1.01. The total nonprotein nitrogen content of the blood on June 28 was 42 mg. On July 3 the nonprotein nitrogen content of the blood was 55 mg. per hundred cubic centimeters, the urea nitrogen content was 28 mg. and the creatinine content was 1.8 mg.

Preliminary fluoroscopic and roentgenographic examination of the chest showed mild bronchial increase of the pulmonary fields, with some small calcifications. There was good excursion of the diaphragm. Studies of the gastrointestinal tract (the patient was given part of a meal) showed a markedly enlarged ptotic stomach. Some fluid was present before ingestion of the barium. At no time were we able to visualize the bulb. At six hours there was about 80 per cent retention in the stomach. Otherwise there was normal progress of the meal. The diagnosis was stenosing ulcer (fig. 11 *A*).

On July 6 the patient was operated on under ether anesthesia. The abdomen was opened through an upper right paramedian incision. Exploration of the abdomen revealed a large liver, extending about 2 inches (5 cm.) below the costal margin; the gallbladder was enlarged and filled with stones; the duodenum had a large ulcer on the posterior side which was adherent to the pancreas; the pancreas was found to contain a small cyst, about the size of a walnut. The hepatogastric and hepatoduodenal ligaments were carefully divided between catgut ligatures, and the posterior portion of the stomach was explored. A large ulcer was found distal to the pylorus and adherent to the pancreas. The gastrocolic ligament and the greater omentum were divided from a point corresponding to the superior edge of the pyloric antrum to a point about 1½ inches (4 cm.) distal to the pyloric sphincter. The pylorus was found to be obstructed. It was divided longitudinally, and the ulcer was clearly seen on the posterior wall of the duodenum.

It was about the size of a 10 cent piece. The longitudinal incision was closed transversely with a continuous lockstitch of no. 0 chromic catgut. The stomach was brought down over the suture line with interrupted silk sutures in two tiers, producing duodenogastric intussusception. The patency of the pyloric sphincter was tested and found to be normal. The greater omentum was sutured down over the field of operation, and the abdomen was closed without drainage

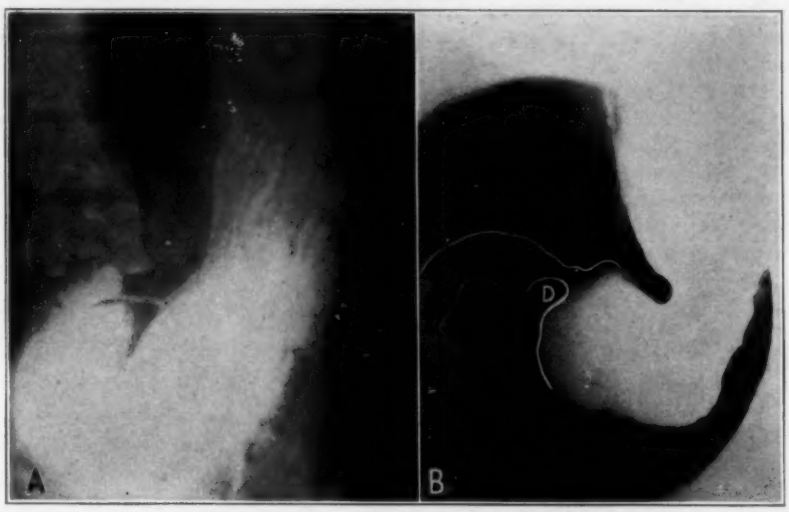

Fig. 11 (case 5).—*A*, roentgenogram (lateral view) taken before operation (note the deformed pylorus); *B*, roentgenogram (retouched) taken two weeks after operation, showing the duodenogastric intussusception after longitudinal division and transverse suture of the pylorus.

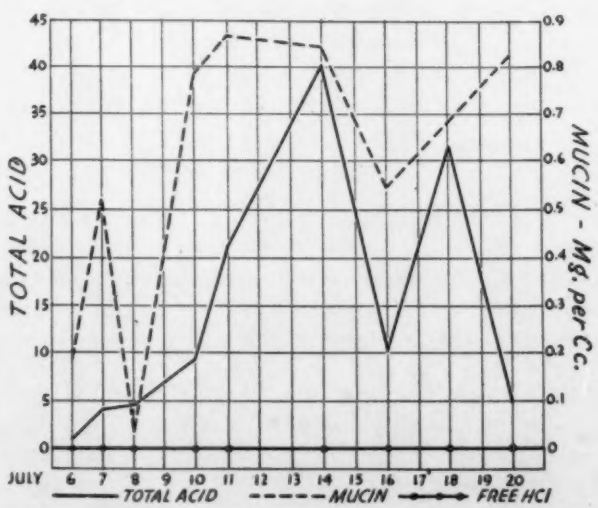

Fig. 12 (case 5).—Chart showing the curves obtained for gastric acids and mucin after operation without the ingestion of an alcohol and histamine meal.

with no. 0 plain catgut on peritoneum and muscle, no. 0 chromic catgut on fascia and interrupted silk sutures on skin (fig. 5).

Postoperative gastric analyses in this case revealed uniform absence of free hydrochloric acid, with a variable total acid content and a high mucin content (fig. 12).

The patient made an uneventful recovery, and on August 20 she was given a barium meal, and some degree of obstruction was still evident at the pylorus. On August 21 (forty-seven days after operation) an alcohol and histamine meal revealed (fourth specimen): total acid, 68; free hydrochloric acid, 60, and mucin, 23.

This case illustrates the feasibility of the operation in cases of posterior adherent ulcer. However, it is suggested that every effort be made to free the ulcer so that the complete operation can be performed. This was the only case in which there was evidence of persistent partial obstruction after one month and the only one in which there was a high acid content after the ingestion of an alcohol and histamine meal, although the mucin value also was high. The patient is now free from symptoms.

SUMMARY OF RESULTS

The operation was entirely satisfactory in all but the last case. There were no deaths, and a follow-up study showed the patients to be clinically well. The acid values remained within normal limits or low and the mucin content high. (According to Anderson and Fogelson,[8] the normal average is 0.4 to 0.7 mg. per cubic centimeter. Our patients showed values up to 2.2 mg.) Roentgenograms made postoperatively showed the invaginated duodenum as a large fold pointing into the lumen of the pyloric antrum. At first it was thought that this might narrow the lumen and cause partial pyloric obstruction in those patients without longitudinal division and transverse suture of the pylorus. However, our follow-up roentgenograms clearly demonstrated that the lateral pull of the stomach opens the pylorus wider than normal. In case 5 the narrowing persisted longer than in the others. In the woman with marked gastroptosis the stomach assumed a more normal position.

CONCLUSIONS

From the small group of cases studied we may conclude that the operation which we have called duodenogastric intussusception should have a place in the surgical attack on peptic ulcer.

The comparative ease of performance, low mortality rate and excellent clinical results seem to indicate that this procedure is rational and practicable.

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8. Anderson, R. K., and Fogelson, S. J.: The Secretion of Gastric Mucin in Man: A Comparative Study in the Normal Subject and in the Patient with Peptic Ulcer in Response to an Alcohol Test Meal, J. Clin. Investigation **15**:169-172 (March) 1936.

ORIGIN OF CARCINOMA IN CHRONIC GASTRIC ULCER

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Almost a century ago, Cruveilhier [1] distinguished between peptic ulcer and carcinoma of the stomach and expressed the opinion that in certain cases malignant degeneration of a peptic ulcer might occur. Since then a voluminous literature, more or less controversial, has accumulated on the question of malignant degeneration of a preexisting benign ulcer of the stomach. It is now generally conceded that so-called "ulcer-carcinoma" [2] does exist as a pathologic entity. The point about which discussion still centers, however, is the incidence of such a lesion.

Cabot and Adie [3] reviewed 82 reports in the literature and noted that approximately half the authors concluded that the development of carcinoma from ulcer occurs in less than 10 per cent of cases.

Newcomb,[4] in a comprehensive survey, listed the statistics of 102 observers who estimated the proportion of gastric carcinomas originating in primary benign ulcers. Among these, 51 stated that not more than 10 per cent of gastric carcinomas arise in peptic ulcer, 74 announced the incidence to be less than 20 per cent and 15 recorded figures exceeding 50 per cent. The entire series covered a range from zero to "over 90 per cent."

Hauser [5] assembled the statistics based on pathologic anatomic studies of a large series of gastric ulcers from several German clinics. He found that only 3.4 per cent of a collected group of 1,774 gastric ulcers showed evidence of carcinomatous change and that the average incidence in the individual reports was 2 per cent. His figures are shown in table

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From the Laboratories and Surgical Services of the Mount Sinai Hospital.

1. Cruveilhier, J.: Anatomie pathologique du corps humain, Paris, J. B. Baillière, 1829-1835, vol. 1; 1835-1842, vol. 2.

2. In this paper the term "ulcer-carcinoma" will be used to designate a carcinoma which has developed in a primary benign chronic gastric ulcer.

3. Cabot, H., and Adie, G. C.: Etiology of Cancer of the Stomach, Ann. Surg. **82**:86, 1925.

4. Newcomb, W. D.: The Relationship Between Peptic Ulceration and Gastric Carcinoma, Brit. J. Surg. **20**:279, 1932.

5. Hauser, G.: Die krebsige Entartung des chronischen Magen- und Duodenalgeschwüres, in Henke, F., and Lubarsch, O.: Handbuch der speziellen pathologischen Anatomie und Histologie, Berlin, Julius Springer, 1926, vol. 4, pt. 1, pp. 497-518.

1, reproduced from his monograph. Two of the most recent papers on the subject, however, reported figures which are at variance. Gömöri [6] found 6 tumors which he designated as ulcer-carcinoma in a group of 64 chronic gastric ulcers and 26 carcinomas. He concluded that "because carcinoma relatively frequently arises in peptic ulcer, such ulcers should be resected whenever possible." Newcomb,[4] on the other hand, found only 6 ulcer-carcinomas in a series of 160 chronic gastric ulcers and 46 carcinomas.

It is obvious that the wide variation in the frequency of ulcer-carcinoma as reported in the literature depends on the type of cases selected for study and on the methods employed. Necropsy material is generally unsuitable because by the time a patient has died as the result of his gastric cancer the lesion has usually progressed to such an

TABLE 1 *(From Hauser's Monograph).—Frequency of Ulcer-Carcinoma Based on Pathologic-Anatomic Statistics*

Author	Clinic	Number of Ulcers	Number of Ulcer-Carcinomas	Per Cent
Scheuermann	Munich	96	1	1.0
Berthold	Berlin	294	4	1.3
Wolowelsky	Basel	139	2	1.4
Cohn	Kiel	295	6	2.0
Greiss	Kiel	136	4	2.9
Schneider	Munich	89	3	3.4
Brinkmann	Kiel	725	40	5.5
Total		1,774	60	3.4
				Average 2%

extent that any possible preexisting ulcer has been completely overgrown by the malignant growth. In 4,400 autopsies done at this hospital, only 1 tumor suggestive of ulcer-carcinoma was found, and the patient with this tumor had died of a cause unrelated to the gastric lesion.

The percentage, of course, varies according to whether the incidence of the condition is sought in a series of ulcers or in a series of carcinomas.

The incidence of ulcer-carcinoma also depends on the type of patients treated in a particular clinic and on the methods of treatment used by that clinic. That is to say, if patients with gastric disturbances apply for treatment early in the course of the disease a larger number of operable carcinomas will be found; this will provide a larger number of specimens for study. Should the method of treating patients with peptic lesions be radical, a larger series of ulcers will also become available. Conversely, if most of the ulcers are treated medically the statistics

6. Gömöri, G.: Carcinoma Arising from Chronic Gastric Ulcer, Surg., Gynec. & Obst. **57**:439, 1933.

obtained from observation of the relatively small number of operative specimens will not provide a true index of the incidence of ulcer-carcinoma.

The wide variations in the reported statistics are probably due to the lack of definite criteria on which to base the diagnosis of ulcer-carcinoma. Newcomb [4] noted in his review of the literature that some of the figures were based on clinical examinations, some on roentgenologic evidence, some on histories and comparatively few on precise anatomic studies. It is on the last-mentioned class that one must depend for the diagnosis of ulcer-carcinoma. Clinical evidence, although frequently suggestive, is too often misleading.

The history presented by the patient is often unreliable. Experience indicates that symptoms of other conditions may clinically simulate the typical symptoms of peptic ulcer. Among these conditions are the psychoneuroses, simple functional disturbances, gastritis, duodenitis, cholecystitis and cholelithiasis. Further, one often sees patients with primary carcinoma of the stomach whose symptoms definitely suggest the presence of peptic ulcers. Maes and McFetridge [7] studied 200 surgical cases of gastric cancer and noted that 50 of the patients had presented histories perfectly typical of ulcer.

Even a prolonged history of symptoms may not be of value in the diagnosis. Hauser [5] stated that the scirrhous form of gastric cancer may produce an illness of several years' duration and quoted Leberts' statistics on 103 cases, in 9 per cent of which the cancer had a duration up to two years and in 8 per cent a duration up to four years.

It is not unusual to find free hydrochloric acid persisting in the gastric contents of patients with undoubted primary gastric carcinoma; even hyperchlorhydria is occasionally noted.

With the aid of roentgen examination it is possible to make an accurate diagnosis of gastrointestinal lesions in a large number of cases. Nevertheless, there is no picture characteristic of ulcer-carcinoma, and not infrequently it is impossible to state from a given examination whether the gastric ulcer is benign or malignant.

Finally, evidence obtained at a previous operation, such as exploratory laparotomy, suture of a perforated gastric lesion or gastroenterostomy, cannot be relied on. Every surgeon is familiar with the difficulty in differentiating between benign ulcer and carcinoma by examination of the lesion in situ. In addition, there are lesions which are difficult to diagnose even when the stomach is opened; microscopic study of such

7. Maes, U., and McFetridge, E. M.: The Place of Surgery in the Therapy of Peptic Ulcer, New York State J. Med. **36**:1399 (Oct. 1) 1936.

lesions is required to determine their nature. Anschütz and Konjetzny [8] found, on the basis of extensive statistics, that in only 3.3 to 6.9 per cent of cases in which gastroenterostomy was performed for ulcer did carcinoma appear later. In 2.5 to 4.9 per cent of these cases, the carcinomas occurred within two years; in only 1.1 to 3.4 per cent did it occur after a longer interval. Only in the latter group could the lesion be assumed to be carcinoma ex ulcere.

Hauser,[5] in commenting on these findings, suggested that if the carcinoma occurred within two years after the gastroenterostomy it might have been present at the time of the operation.

ANATOMIC CONSIDERATIONS

The anatomic diagnosis of ulcer-carcinoma involves two problems: first, to establish proof of the preexistence of a benign chronic peptic ulcer and, second, to demonstrate the presence of malignant degeneration.

DIAGNOSIS OF CHRONIC GASTRIC ULCER

Gross Features.—Chronic callous gastric ulcer, as a rule, occurs singly and is generally situated along or close to the lesser curvature in the antral portion of the stomach. It may occasionally be found near the cardia or in the body of the stomach, but this is uncommon. The defect may be round, oval or eccentric in shape, with its long axis either parallel with the lesser curvature or horizontal so that it saddles it. The margins are usually smooth, and the surrounding mucous membrane is injected and inflamed in varying degree, yet is freely movable on the submucosa. While the edges may have a sharply punched out appearance, it is more common to find the superior edge overhanging and steep while the distal border slopes upward gradually in steplike or terrace formation, so that a longitudinal cross section through the center of the lesion resembles a fish hook or an inverted funnel. Hauser [5] concluded that this characteristic shape of the ulcer is dependent on the normal vascular distribution in the gastric wall. This opinion is opposed to the mechanical theory supported by Rothman,[9] Stromeyer,[10] and others who have contended that the chronic gastric ulcer retains its characteristic form mainly through the mechanical effect

8. Anschütz, W., and Konjetzny, G. E.: Die Geschwülste des Magens, in Billroth, T., and Luecke, A.: Deutsche Chirurgie, Stuttgart, Ferdinand Enke, 1921, vol. 46, pt. 1, pp. 72-102.

9. Rothman, A.: Chronisches Magengeschwür in seiner Beziehung zum Magenkrebs, Arch. f. klin. Chir. **175**:201, 1933.

10. Stromeyer, F.: Die Pathogenese des Ulcus venrticuli, zugleich ein Beitrag zur Frage nach den Beziehungen zwischen Ulcus und Carcinom, Beitr. z. path. Anat. u. z. allg. Path. **54**:1, 1912.

of the passage of the gastric contents along the magenstrasse. The depth of the crater varies considerably in different specimens, depending on the phase in which the ulcer is seen, that is, the degree of destruction relative to the amount of healing that has taken place. The surface of the base of the ulcer may be covered with mucus, fibrin, necrotic débris or mucopurulent exudate. Considerable inflammation is frequently evident on the serosal surface in the region of the ulcer with the production of adhesions to surrounding structures, such as the transverse mesocolon, the liver and, more particularly, the pancreas. Occasionally, penetration has advanced to such a degree that the entire thickness of the base of the ulcer is destroyed and the floor of the ulcer consists actually of the agglutinated surface of the liver or the pancreas.

Occasionally, however, a chronic peptic ulcer may present an atypical gross appearance because of the severe distortion produced by cicatrization and adhesions. This may also occur after a previous surgical operation on the stomach, such as suture of a free perforation.

Histologic Features.—The microscopic examination of the chronic gastric ulcer necessarily includes a consideration of both its base and its margins. Even more than the gross picture, the microscopic picture of the structure of the peptic ulcer depends on the phase of destruction and repair present at the time of examination. In the active stage, the bed of the ulcer presents several fairly well defined zones (Askanazy [11]): (1) a film of mucus on the surface; (2) a fibrinopurulent layer; (3) a layer of necrotic débris enmeshed by fibrin; (4) a zone of granulation tissue; (5) a stratum of dense fibrous tissue showing the evidences of chronic inflammation (in some cases there is considerable vascularization; in others blood vessels may be scarce), and (6) the serosal layer.

When the process of repair predominates, the base of the ulcer consists essentially of a mass of scar tissue on the surface of which is a narrow layer of necrotic material and fibrinopurulent mucus. If there has been severe destruction of the gastric wall the floor may be extremely thin, and occasionally one finds pancreatic or hepatic tissue in the base of the defect.

Most important is the fact, described by Hauser [5] and accepted by most authors, that the base of the ulcer is almost always entirely free of muscularis. The segment of the muscularis corresponding to the area of the ulcer is completely destroyed, and the free ends of the muscular layer characteristically bend upward into the ulcer margin, sharply demarcated against the connective tissue of the base. This is in contrast to the condition, seen in many carcinomas, in which there is retention of the muscularis in the base with splitting and separation

11. Askanazy, M.: L'étiologie et la pathogénie de l'ulcère rond de l'estomac, Rev. méd. de la Suisse Rom. **40**:477, 1920.

of the muscle fibers by the infiltrating malignant cells. Frequently, this turning up of the muscularis into the ulcer margins can be seen in cross sections with the naked eye.

Newcomb [4] described an additional feature which he considered pathognomonic of benign chronic gastric ulcer. This consists of the close approximation or fusion of the muscularis propria and the muscularis mucosae at the edge of the ulcer, produced by the contraction of scar tissue in the process of healing. He found this condition in some part of all but 1.5 per cent of 154 chronic gastric ulcers. Gömöri,[6] however, reviewed 64 cases of chronic ulcer of the stomach and found actual fusion of the two muscular layers in but 34 cases. There was some approximation in 22 cases, and the position was unchanged in 5 cases. In 3 instances distinct progressive separation of both layers toward the edge of the ulcer was observed. He stated that whether or not the sign described by Newcomb [4] is found depends largely on the phase of destruction or healing which happens to prevail at the time of the examination.

The blood vessels in the floor of the ulcer frequently show endarteritis and thrombophlebitis. All stages of involvement may be encountered, including thrombosis, organization and recanalization. Occasionally a fortunate section shows a vessel near the surface undergoing destruction, thus demonstrating the mechanism of hemorrhage.

The reparative process on the part of the mucous membrane at the edge of the ulcer often produces bizarre epithelial overgrowths. These may occur as small clumps of cells, as narrow cords or as abnormal acini made up of cells which may exhibit varying degrees of atypia. These structures may even become detached and buried in the contracting cicatrix of the base. Newcomb found the evidences of atypical epithelial proliferation in 29 per cent of 161 chronic gastric ulcers, and Dible [12] observed them in 32 per cent of 126 ulcers. Several authors have called attention to the fact that the heterotopia and atypia of the regenerating epithelium have frequently led to an erroneous diagnosis of carcinoma. This probably accounts for the high incidence of carcinomatous degeneration of chronic peptic ulcers reported in some series.

DIAGNOSIS OF CARCINOMA

It is not within the province of this paper to discuss the criteria for the diagnosis of cancer. These depend on the usual pathologic features of anaplasia, local invasion and metastasis. As has been indicated, great care must be exercised in differentiating nonmalignant heterotopic atypical epithelium from true carcinoma.

12. Dible, J. H.: Gastric Ulcer and Gastric Carcinoma, Brit. J. Surg. **12**:666, 1924.

DIAGNOSIS OF ULCER-CARCINOMA

By definition, an ulcer-carcinoma of the stomach is a carcinoma which has developed secondarily in a preexisting chronic peptic ulcer. To prove this sequence of events is by no means simple.

The macroscopic examination is of little value, for it is well known that the typical gross form of chronic benign ulcer may be exactly reproduced by an ulcerated primary carcinomatous growth.

Even the characteristic microscopic features of chronic callous peptic ulcer may be duplicated in ulcerated cancer (Hauser,[5] Stromeyer,[10] Anschütz and Konjetzny,[8] Moszkowicz,[13] Dible [12] and Newcomb [4]). I examined 100 surgical specimens of primary gastric carcinoma and readily confirmed this fact. In addition, particular attention was paid to the relationship of the muscularis mucosae and the muscularis propria in the ulcerated carcinomas, and they were observed to be closely approximated in 3 specimens. This finding is in disagreement with Newcomb's contention that this sign is pathognomonic of *primary* peptic ulceration. The approximation of the two muscular layers appears to be merely a frequent result of chronic peptic ulceration and may therefore also be observed in a secondarily ulcerated carcinoma in which peptic digestion has proceeded to a degree to involve normal tissue and produce the typical pathologic picture of chronic peptic ulcer.

Because of the possible similarity between primary peptic ulcer and ulcerated carcinoma and the lack of a specific anatomic feature which would indicate the preexistence of a benign lesion, it seems necessary to follow the most conservative and critical criteria for the diagnosis of ulcer-carcinoma, such as were outlined by Hauser [5] and supported by Borrmann [14] and by Anschütz and Konjetzny.[8] These criteria require that, in addition to the presence of the characteristic features of chronic peptic ulcer, the carcinoma must be localized to a narrowly circumscribed area of the margin of the ulcer while the base is entirely free of cancer or is, at least, only slightly infiltrated adjacent to the focus of origin of the tumor. This picture, of course, is seen only with the carcinoma in the earliest stage. In more advanced stages of ulcer-carcinoma, according to Spilsbury,[15] the malignant cells may advance from the margin of the ulcer into the tissue of the base, where they must traverse dense connective tissue poorly supplied with blood and having a precarious

13. Moskowiscz, L.: Ueber einen Fall von jungen "Ulcuscarcinom" des Magens, Virchows Arch. f. path. Anat. **253**:511, 1924.

14. Borrmann, R.: Ulkuskarzinom, in Henke, F., and Lubarsch, O.: Handbuch der speziellen pathologischen Anatomie und Histologie, Berlin, Julius Springer, 1926, vol. 4, pt. 1, pp. 902-917.

15. Spilsbury, B. H., and Ryffel, J. H.: The Morbid Anatomy and Histology of Gastric Ulcer, with Special Reference to Its Relationship to Cancer of the Stomach, Proc. Roy. Soc. Med. **15**:25, 1921-1922.

lymph flow; or they may grow into the normal wall of the stomach, where a loose arrangement of the tissues, abundant blood supply and a free lymph flow exist to facilitate their spread. From the knowledge of the behavior of carcinoma generally, it seems probable that such a tumor would infiltrate the surrounding healthy tissues more readily than the scar tissue in the base of the ulcer. Thus, as illustrated by Borrmann,[14] the ulcer would be eccentric in relation to the area of carcinoma rather than in its center. In the advanced stages of the disease the diagnosis is extremely difficult and may even be impossible.

A critical evaluation of the criteria mentioned, however, reveals two possible sources of error. Hauser,[5] Borrmann,[14] Stromeyer,[10] Anschütz and Konjetzny [8] and others have discussed the possibility of the independent occurrence of ulcer and carcinoma anatomically close to one another in the same stomach. The two lesions, by their progressive enlargement, might finally meet and thus produce the illusion of a carcinoma arising in the edge of a chronic ulcer. As pointed out by Gömöri,[6] however, the tumor would tend to be most voluminous at its focus of origin rather than at the margin of the ulcer. The other point to be considered in the diagnosis of ulcer-carcinoma is the possibility of the complete or almost complete ulceration of a primary new growth so that there remains little, if any, carcinomatous tissue and what little there is can be found only after careful microscopic examination (Moszkowicz,[13] Stromeyer,[10] Billroth,[16] Ziegler [17]). Such severe destruction would probably also explain the production of the "ring" form of carcinoma, which consists of a cancer-free typical peptic ulcer base surrounded by a residual circle of neoplastic tissue (Stromeyer,[10] Borrmann [14]). Gömöri,[6] on the other hand, concluded that such a lesion might be a primary peptic ulcer in whose border carcinoma has developed in simultaneous multicentric foci which have fused to form a ring. As evidence in support of this theory, he presented a case in which the ring of cancer was incomplete and also cited the report [18] of a similar lesion. This evidence does not appear to be conclusive, however. In view of the frequency with which extensive ulceration of gastric carcinoma is observed, it is probably more logical to account for the incomplete circle on the basis of additional destruction of a segment of the circumference of the carcinomatous ring.

In the light of these criticisms, it seems that there is a possibility that carcinoma originating in peptic ulcer may not exist. The term ulcer-carcinoma, therefore, should be used only if these considerations are borne in mind.

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16. Billroth, cited by Anschütz and Konjetzny.[8]

17. Ziegler, cited by Anschütz and Konjetzny.[8]

18. Klein, E., and Demuth, F.: Zur Frage des Ulcus-Karzinoms des Magens, Beitr. z. path. Anat. u. z. allg. Path. **79**:117, 1927; cited by Gömöri.[6]

MATERIAL AND METHODS

The material studied was drawn from a series of 1,057 gastrectomy specimens received in the pathologic laboratories at the Mount Sinai Hospital from January 1928 to July 1936 and from 4,400 autopsies performed during the same period. The surgical specimens were classified as shown in table 2. From the careful routine gross and microscopic examinations of this rather extensive material, a provisional diagnosis of ulcer-carcinoma of the stomach was made for 11 specimens. Ten of these were from the surgical series and 1 from the postmortem series. The evidence furnished by the routine examination was not considered sufficient for the establishment of a definite diagnosis. Consequently, these specimens were made the subject of special investigation.

The routine microscopic sections were first carefully examined. Three specimens were eliminated because they did not satisfy the criteria of ulcer-carcinoma. Two of these were considered to be ulcerated carcinomas and 1 a chronic

TABLE 2.—*Gastrectomy Material Received from Jan. 1, 1928 to July 1, 1936.*

Gastric ulcer			139
Gastric carcinoma			344
Duodenal ulcer			351
Healed ulcers	duodenal and gastric	1	11
	gastric	3	
	duodenal	7	
Gastritis			59
Gastritis and erosions			6
Duodenitis			19
Duodenitis and erosions			8
Duodenitis and gastritis			18
Jejunal or gastrojejunal ulcer			57
Sarcoma (various types)			22
Hodgkin's disease			2
Syphilis			1
Miscellaneous			10
Condition suggestive of ulcer-carcinoma			10
Total			1,057

peptic ulcer with definite atypical hyperplasia of the mucous membrane. The remaining 8 were then studied by means of the following technic:

A full size outline drawing was made of the gross specimen. The entire ulcer was then cut serially into numbered blocks, and these were accurately outlined in the drawing. Microscopic sections were cut from each block and stained with hematoxylin and eosin. Representative sections were also stained by the Van Gieson method to determine the arrangement of the muscular layers. Each section was examined for the various features of chronic peptic ulcer and for the presence of carcinoma. An outline drawing was then made of each microscopic section to show the distribution of the malignant growth. Finally, the entire lesion was reconstructed in the form of a composite relief drawing, thus demonstrating the extent of the tumor in relation to the ulcer's base, its margins and the surrounding tissues. This method was suggested by Konjetzny's [19] diagrammatic illustration of 1 of his 2 reported ulcer-carcinomas.

19. Konjetzny, G. E.: Ueber die Beziehungen der chronischen Gastritis mit ihren Folgeerscheinungen und des chronischen Magenulcus zur Entwicklung des Magenkrebses, Beitr. z. klin. Chir. **85**:455, 1913.

REPORT OF CASES

CASE 1.—A 33 year old woman was admitted to the surgical service of Dr. A. A. Berg. Her symptoms, which were of two years' duration, consisted of daily attacks of epigastric pain, relieved by vomiting and unrelated to the ingestion of food. The pain was constant for three days before her admission to the hospital. A gastric test meal was attempted, but the contents of the stomach were bloody. The stool gave a positive reaction to the test for occult blood. The clinical impression was that of a penetrating peptic ulcer. The patient's condition improved when she was given a Sippy diet. A series of gastric roentgenograms taken after clinical improvement revealed a penetrating lesion in the antrum of the stomach, which appeared to be benign. A subtotal gastrectomy was performed.

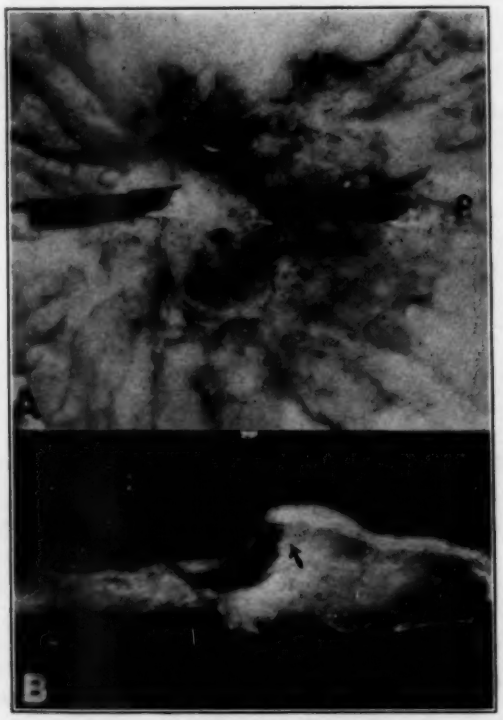

Fig. 1.—*A*, photograph of an ulcer-carcinoma (?). Note the typical form of chronic peptic ulcer. *P* indicates the proximal side of the specimen. *B*, photograph of a longitudinal cross section. Note the overhanging superior lip and the sloping distal margin of the ulcer. The arrow points to the sharply demarcated muscularis turned up into the edge of the ulcer.

Examination of the specimen revealed an oval ulcer 2.5 by 1.8 cm. on the lesser curvature in the antrum of the stomach (fig. 1 *A*). The proximal edge of the ulcer was overhanging, and the distal margin sloped up gradually. The base was red, and at one side the staircase appearance of the ulcer was distinct. The distal edge was rough in contrast to the smooth appearance of the mucosa on the proximal side, and at this point the mucosa was mobile whereas at the distal margin it was fixed. No lymph nodes were found in the gross specimen.

A longitudinal section of the ulcer presented the typical fish hook form of chronic peptic ulcer, and even macroscopically the muscularis could be seen turning upward into the edge of the ulcer (fig. 1 *B*).

Microscopically the lesion showed all the characteristic features of chronic peptic ulcer (fig. 2). A small area of carcinoma was localized at the distal margin (fig. 3). The base was free from carcinoma. Early invasion of the submucosa was seen in only one block. There was considerable atypical epithelial hyperplasia of the mucosa adjacent to the carcinomatous area. In addition, two distinct areas of adenocarcinoma were noted at a little distance from the main focus. There seemed to be a gradual transition between the atypical epithelium of the hyperplastic mucous membrane and the areas of carcinoma. Microscopically several small lymph nodes were seen which were free of metastatic involvement. Figure 4 shows the final relief drawing illustrating the distribution of carcinomatous growth.

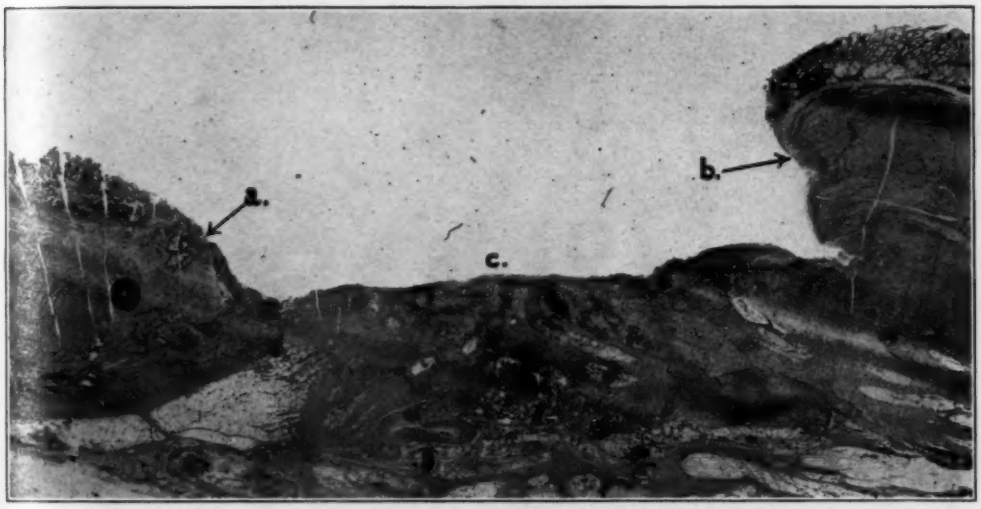

Fig. 2.—Low power photomicrograph of a section taken from the block shown in figure 1 *B*. Arrow *a* points to the area of carcinoma at the distal edge of the ulcer; arrow *b* indicates the fusion of the muscularis mucosae and muscularis propria, and arrow *c* marks the characteristic callous peptic ulcer base, in which the muscularis has been completely destroyed. Note the many blood vessels in the base; these show inflammatory changes.

Case 2.—The patient was an electrician 47 years of age. His symptoms consisted essentially of postprandial epigastric pain over a period of six years, relieved by a modified Sippy diet. He was operated on at another hospital for the suture of a free perforation of a large callous ulcerated lesion of the anterior wall of the stomach in its midportion adjacent to the lesser curvature; at that time the lesion was considered to be possibly malignant. Since then, for one year, he had had postprandial pain in the epigastrium, eructations, pyrosis and occasional vomiting. The pain was relieved by the ingestion of milk and alkalis. He was admitted to this hospital under the care of Dr. A. O. Wilensky, and a subtotal

gastrectomy was performed. Considerable difficulty was encountered during the operation in separating the stomach from the liver and the pancreas, to which it was densely adherent.

The specimen presented a distorted appearance, probably because of the extensive adhesions and the previous surgical procedure. Along the inferior edge of the specimen there was infiltration with scar tissue, and there were two ulcerated areas which had probably formed one large ulcer in the intact stomach. The lesion measured 3 by 2.5 cm. The base consisted partially of adherent brownish green hepatic tissue. The margin of the ulcer was somewhat indurated by cicatricial tissue. There was thick scar tissue beneath the ulcer. On reconstruction of the specimen it was apparent that the ulcer was at the pyloric end, saddling the lesser curvature. No lymph nodes were found.

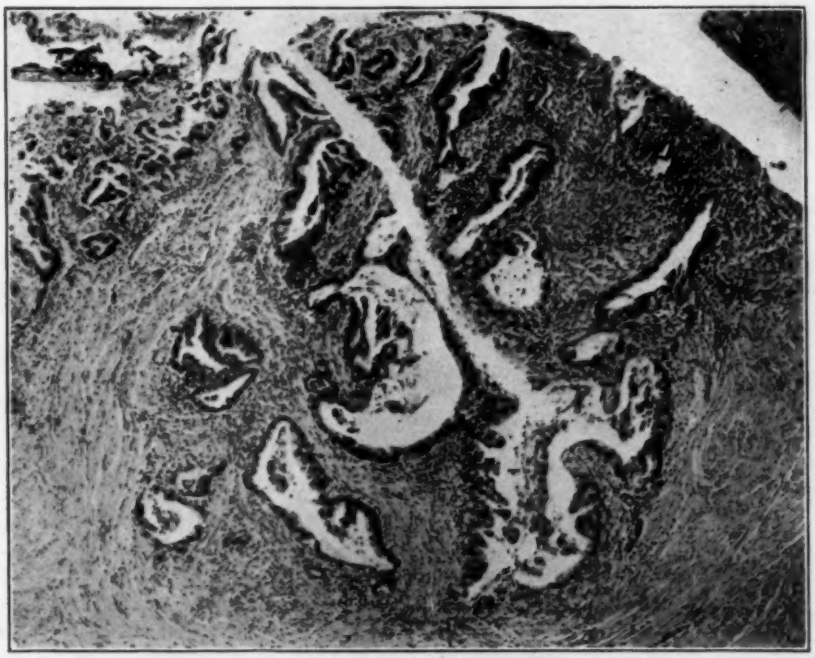

Fig. 3.—Medium power photomicrograph of the area of carcinoma indicated by the arrow in figure 2.

Microscopic examination revealed all the typical features of chronic peptic ulcer. Three distinct areas of adenocarcinoma, well localized at the ulcer margin, were found, as shown in figures 5 and 6. Evidence of early carcinomatous invasion was found in only one block.

Comment.—According to the pathologic criteria employed in this study, the lesions in cases 1 and 2 might be considered examples of chronic benign peptic ulcers which had undergone malignant degeneration. Both lesions presented all the characteristic features of chronic peptic ulcer; there were localized areas of carcinoma in the ulcer margins, and the ulcer floors were completely free of cancerous infiltration.

Nevertheless, as has been noted, these criteria are not exempt from possible criticism, for precisely similar pathologic pictures might conceivably be produced by either of two other processes, namely, the almost complete ulceration of a primary carcinoma and the independent occurrence of ulcer and carcinoma anatomically adjacent to one another, with subsequent fusion. Therefore, it must be conceded that although the lesions in these 2 cases were suggestive of so-called ulcer-carcinoma on the basis of the strict criteria employed their pathogenesis is still open to question. It does not seem possible with the morphologic evidence available to arrive at a more definite differential diagnosis at the present time.

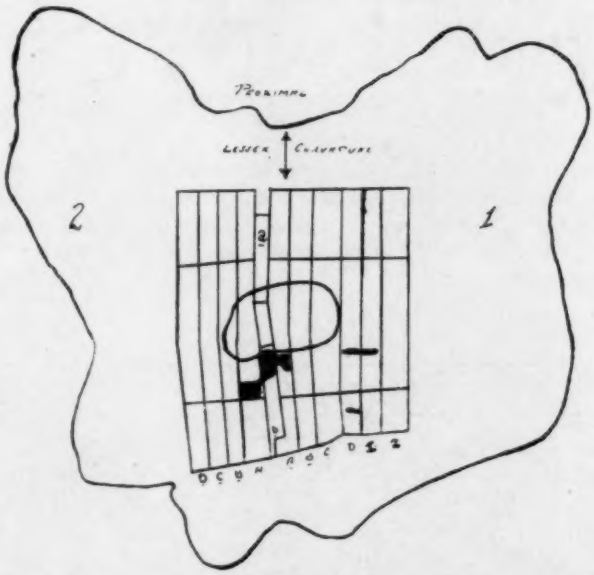

Fig. 4.—Composite relief drawing made from microscopic sections of serial blocks to show the location and extent of the carcinomatous growth. The solid black areas represent the multiple neoplastic foci. The base of the ulcer is free of cancer.

The next case is reported as an instance of the ring form of carcinoma, which has been described. In my opinion, the lesion was probably an ulcerated primary carcinoma rather than a primary ulcer with multicentric neoplastic degeneration in its borders.

Case 3.—The patient was a 44 year old man who was admitted to the surgical service of Dr. A. A. Berg with a five year history of gastrointestinal symptoms. These consisted of periodic attacks of epigastric burning pain radiating to the right side and to the back, accompanied by epigastric distention, sour eructations and occasional vomiting. The pain appeared about two hours after each meal and was relieved by the ingestion of food and of alkalis. The attacks would

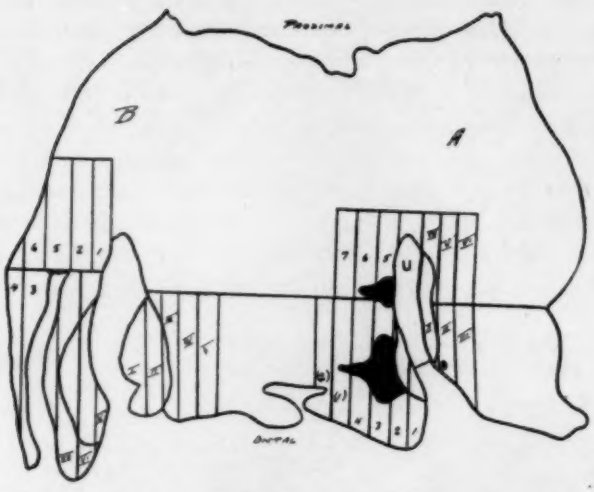

Fig. 5.—Ulcer-carcinoma (?). Composite relief drawing showing localized area of carcinoma at the ulcer margin. Note the multiple foci of neoplastic growth, represented by the solid black areas. The ulcer base is uninvolved. The unusual gross picture is due to cicatricial distortion and contraction of the specimen by fixation in solution of formaldehyde.

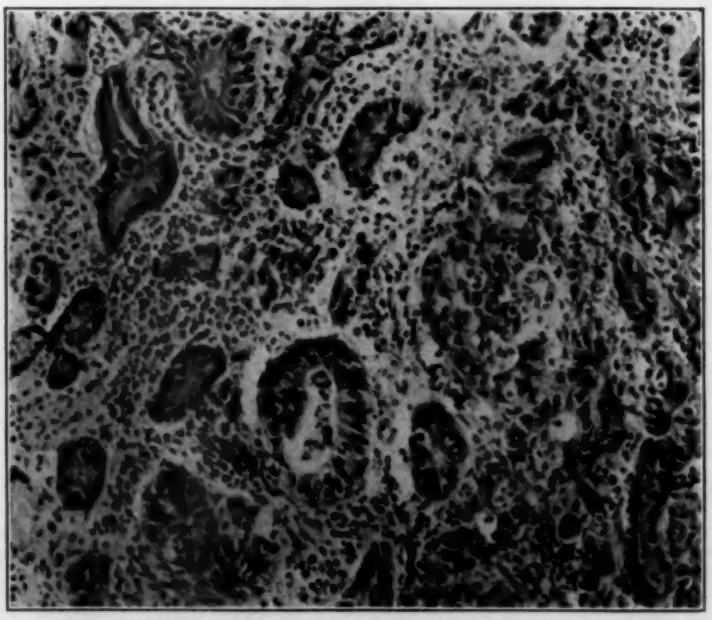

Fig. 6.—High power photomicrograph showing carcinoma.

occur over a period from two to four months and a free interval of a few months would follow. A liberal Sippy diet during the past two years more or less controlled the symptoms, which, however, recurred after dietary indiscretion. One year prior to his admission he was examined at another institution. The Ewald test meal disclosed a free acid content of 92 per cent and a total acid content of 104 per cent. The gastrointestinal roentgen examination at this time showed a widened pyloric interval and a small penetrating lesion in the prepyloric region on the lesser curvature of the stomach. The diagnosis was pyloric ulcer and penetrating gastric ulcer on the lesser curvature of the stomach. Roentgen examination two weeks before admission to this hospital revealed a narrowing in the prepyloric region which was suggestive of a neoplasm.

On his admission, the stool gave a positive reaction to the guaiac test for occult blood. The Rehfuss test meal revealed bloody gastric contents which showed a maximum free acid content of 44 per cent and a total acid content of 68 per cent.

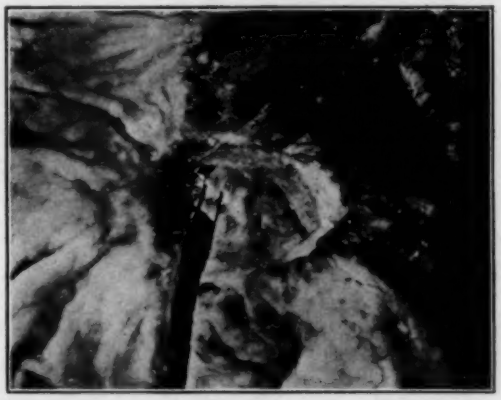

Fig. 7.—Photograph of a "ring form" carcinoma. Note the typical form of chronic peptic ulcer.

Roentgen examination of the stomach at this time showed an irregular constriction of the antrum, extending from the pylorus approximately to the reentrant angle. There seemed to be a large ulcer within the lesion. There was slight delay in gastric motility. These findings suggested an ulcerating lesion in the antrum of the stomach, which was considered to be probably malignant. A subtotal gastrectomy was performed.

Examination of the specimen revealed a crater-like ulcer 2.5 cm. in diameter on the lesser curvature of the antral portion of the stomach (fig. 7). There was penetration of the layers of the stomach wall for 1 cm. The mucosa around the edge of the ulcer was fairly easily movable over the deeper layers, and there was no heaping-up of the mucous membrane.

Microscopic sections showed all the characteristic features of chronic peptic ulcer and, in addition, a carcinomatous growth distributed as shown in figure 8. The question mark in block II B4 indicates the area in which the mucosa was absent at the edge of the ulcer because of a technical error. From the entire picture, however, it was considered probable that the ring of carcinoma was complete.

The following 2 cases are presented to illustrate the occurrence of typical chronic peptic ulceration in a primary carcinoma and the value of the serial block examination in the differential diagnosis of gastric ulcers.

Case 4.—A man 42 years of age was admitted to the surgical service of Dr. R. Lewisohn. His illness began eighteen months prior to admission, with symptoms of epigastric pain and abdominal distention which occurred one and one-half to two hours after each meal and were readily relieved by the use of sodium bicarbonate and by the ingestion of milk and cream. There was mild anorexia,

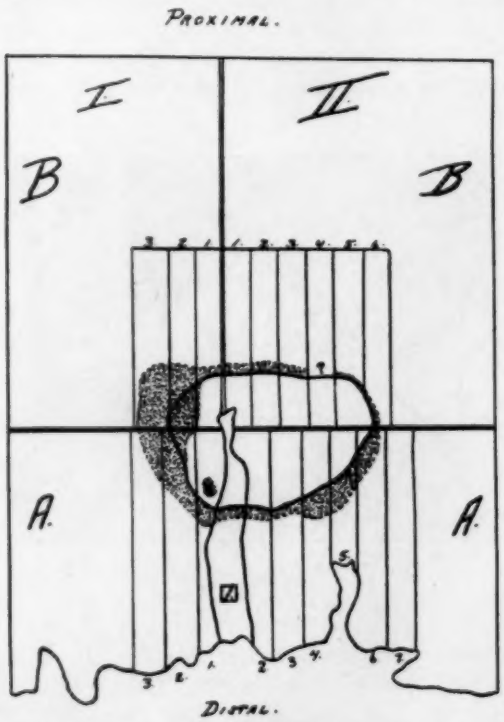

Fig. 8.—Composite relief drawing showing the "ring form" of carcinoma. The stippling represents malignant growth. The base of the ulcer shows only slight carcinomatous infiltration.

and he vomited on several occasions. For six months his diet was restricted almost exclusively to milk and cream administered every one to two hours. This resulted in only partial relief of pain.

Roentgen examination of the stomach two weeks before admission revealed the presence of a niche at the reentrant angle. The vomitus gave a strongly positive reaction to the guaiac test for occult blood. The Wassermann test was negative. The clinical diagnosis was chronic peptic ulcer of the stomach. At operation, a deeply penetrating ulcer above the reentrant angle was found, and a subtotal gastrectomy was performed.

The opened stomach presented a large oval ulcer saddling the lesser curvature 5 cm. above the pyloric ring (fig. 9*A*). The defect measured 2 by 2.5 cm. Its margins were smooth and had a punched-out appearance, and its base was deep, extending into the gastric wall for 1.25 cm. Macroscopically the surrounding mucous membrane did not appear abnormal. In the longitudinal section the fish hook shape was noted, and even with the naked eye the upturning of the muscularis into the base of the ulcer could be seen (fig. 9*B*).

The first block taken for microscopic section was cut along the midline of the lesion and measured 6.25 cm. in length (fig. 10). The base and margins of the ulcer showed all the characteristic features of chronic peptic ulcer, including the approximation of the muscularis mucosae and the muscularis propria. The

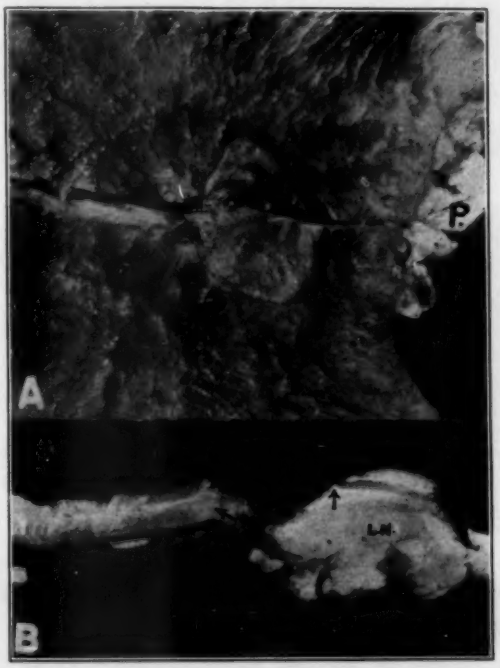

Fig. 9.—*A*, photograph of an ulcerated carcinoma. Note the typical form of chronic peptic ulcer. *P* indicates the proximal side of the specimen. *B*, photograph of a longitudinal cross section, showing the typical form of chronic peptic ulcer. Arrows point to the sharply demarcated muscularis turned into the ulcer margin. (Note the similarity to the section in figure 1*B*). *L.N.* indicates a lymph node involved by metastatic carcinoma.

mucous membrane of the superior segment of the block was completely involved by adenocarcinoma. The base of the ulcer was free of tumor except in the area just adjacent to the superior border, where there was slight infiltration. The mucous membrane of the distal segment presented epithelial proliferation, with cellular atypia and several small islands of carcinoma cells. A lymph node present in the section showed advanced metastatic involvement.

From this block a provisional diagnosis of ulcer-carcinoma was ventured. However, complete examination of the ulcer and the surrounding area by the

serial block technic proved the lesion to be obviously a primary carcinoma which had undergone typical peptic ulceration (fig. 10).

CASE 5.—A man 70 years of age was admitted to the medical service of Dr. G. Baehr. He had had epigastric pain and gaseous eructations, relieved by the use of alkalis, for five years and "cigaret cough" for several years. Two weeks before admission he began to notice severe epigastric pains after eating and also during the night, and he vomited several times. He lost several pounds during one year.

On admission, he was thin and pale. The stool gave a positive reaction to the guaiac test for occult blood. The Rehfuss gastric test meal disclosed a maximum free acid content of 40 per cent and a total acid content of 56 per cent. A series of gastrointestinal roentgenograms revealed a persistent prepyloric defect involving principally the side of greater curvature of the stomach. There was delay in gastric motility, evidenced by a 30 per cent residue in the stomach after six hours

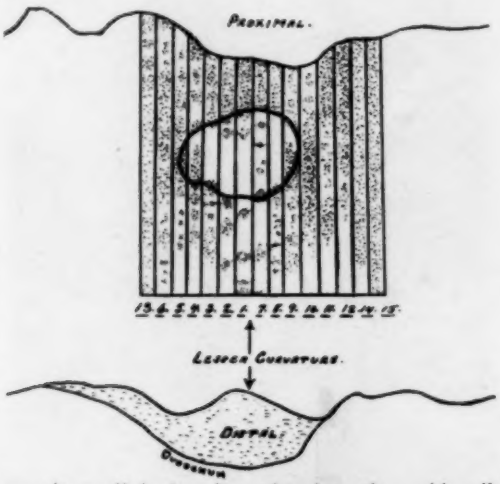

Fig. 10.—Composite relief drawing showing the wide distribution of the carcinomatous infiltration, represented by the stippling.

and moderate residue after twenty-four hours. It could not be stated definitely whether this prepyloric defect was due to the presence of an old chronic ulcer or whether it was malignant. However, the clinical history seemed to favor the diagnosis of chronic ulcer.

The patient's poor general condition precluded operation at this time, and he was given a Sippy diet. Under this regimen he was free of pain and was sent home to continue this treatment.

He was readmitted to the hospital several days later, acutely ill, dehydrated and emaciated, with a temperature of 103 to 104 F. The blood culture yielded Bacillus coli. The patient died four days later.

At autopsy there was observed an infiltrating squamous cell carcinoma of the right main bronchus with metastases to the regional lymph nodes, bronchopneumonia, pleuropericarditis and mediastinitis. In addition, there was a gastric lesion which was situated on the lesser curvature of the stomach 1 cm. proximal to the pyloric ring. It consisted of a large oval ulcer measuring 5 by 3 cm. (fig. 11 *A*).

The upper and lateral edges were slightly hemorrhagic, rounded and somewhat undermined. The distal edge was distinctly piled up and was more prominent than the remainder of the ulcer margin. The border here sloped gradually to a finely granular base. A section of this piled-up edge revealed uniformly gray tissue 1 cm. in thickness. The serosa at the site of the ulcer showed no changes. Macroscopically the gastric lymph nodes appeared normal.

Histologic examination of the original sections (*O* and *O'* in figure 11 *B*) led to the provisional diagnosis of ulcer-carcinoma. In section *O* there was a localized area of adenocarcinoma at the margin of the ulcer. There was also a partial adjacent infiltration of the base. Both of these carcinomatous areas showed all

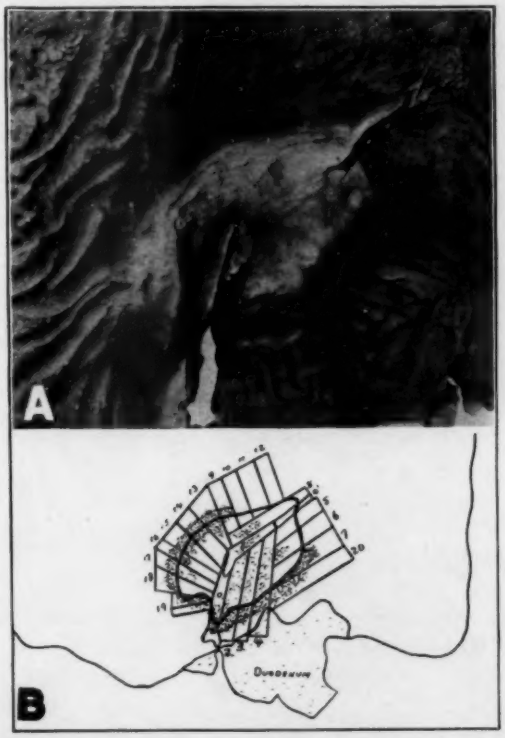

Fig. 11.—*A*, photograph of an ulcerated carcinoma. Note the typical form of chronic peptic ulcer. *B*, composite relief drawing showing the extent of the carcinomatous growth, represented by the stippled area.

the characteristic features of chronic peptic ulcer. Section *O'* was typical of peptic ulcer and was also entirely free of carcinoma. Sections examined by the serial block technic, however, revealed widespread carcinomatous infiltration of the base and borders of the ulcer, except in blocks 5, 10, 11, and 12. Microscopically the lymph nodes showed no metastatic involvement.

On the basis of the criteria previously discussed it is impossible to state definitely whether this lesion was an advanced ulcer-carcinoma or an eccentrically ulcerated carcinoma. The latter diagnosis is considered more probably correct, because were the growth an advanced ulcer-carcinoma one would expect in this

stage of growth much more widespread carcinomatous invasion of the adjacent stomach wall, commensurate with the degree of involvement of the base of the callous ulcer.

Of the remaining 3 lesions which were studied by the serial block method, 2 proved to be ulcerated carcinomas and 1 a benign ulcer with atypical epithelial hyperplasia.

SUMMARY AND CONCLUSIONS

The criteria for the diagnosis of so-called ulcer-carcinoma are discussed and evaluated.

The characteristic pathologic features of chronic benign peptic ulcer may be exhibited in every detail by primary gastric carcinoma which has undergone peptic ulceration.

There is no one pathologic feature which may be considered pathognomonic of the preexistence of a chronic benign peptic ulcer.

A serial block method for the complete anatomic study of gastric ulcerations is described.

In a series of 141 cases of chronic gastric ulcer and 353 cases of gastric carcinoma there were but 2 cases in which the diagnosis of ulcer-carcinoma could be suggested on the basis of certain pathologic criteria.

The diagnosis of ulcer-carcinoma, even though based on the strictest available criteria, may still be open to criticism.

It is concluded that malignant degeneration of chronic gastric ulcer, if it occurs at all, is rare.

Because of the rarity of proved ulcer-carcinoma, there is insufficient justification for early radical surgical treatment of gastric ulcer based on the possible danger of malignant degeneration.